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Evaluation of soft-shell data for legal-sized male Dungeness Crabs (*Metacarcinus magister*) in Crab Management Areas E-S, E-T, G and H in British Columbia, 2009 to 2013

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Dungeness Crabs (*Metacarcinus magister*) increase in size incrementally by moulting. In southern British Columbia, Canada, legal-sized (≥ 165 mm carapace point-to-point width) male crabs are believed to moult generally during the winter and spring, although the specific timing is unknown and can be variable. After moulting, the new shell is soft, and gradually hardens over the next two to three months. While in this soft-shell condition, crabs are more vulnerable to being injured and killed as a result of reduced protection from a hardened exoskeleton. To better protect legal-sized male crabs in Crab Management Areas (CMAs) E-S, E-T, G and H, fisheries managers have requested information regarding the timing and variability when these crabs are soft-shelled. As a result, a collaborative research program involving Fisheries and Oceans Canada (DFO) and the crab fishing industry was conducted from 2009 to 2013. Crab biological data were collected in two ways:

1. using standardized trap gear fished independently of the commercial fishery, and
2. from commercial vessels actively fishing.

Two analytical methods were used:

1. by examining the proportion of soft-shell legal-sized males to all legal-sized male crabs sampled, and
2. by examining the numbers of soft-shell legal-sized male crabs collected per trap (CPUE).

Two models, a proportion model and a CPUE model, were developed within a Bayesian framework to estimate the timing of peak proportion and peak relative abundance, respectively, of soft-shell legal-sized male crabs based on observed data from the two sampling programs. Analyses also determined time periods (including estimates of uncertainty) when the proportion and relative abundance of soft-shell legal-sized males were 95%, 90%, 85%, 75% and 50% of peak values. The peak proportion and peak relative abundance from analyses of soft-shell legal-sized male crabs in the four CMAs ranged from March 5 to 27. Using proportion data from the fishery-independent sampling program, and a 10% reduction from the peak (0.90 × Peak), 48% of the legal-sized male crabs in CMA H were soft on any given day between January 22-May 7 (± 10 days), with a peak on March 15, 58% of the legal-sized male crabs in CMA E-S were soft on any given day between January 15-May 10 (± 12 days), with a peak on March 12, 43% of the legal-sized male crabs in CMA E-T were soft on any given day between January 26-May 16 (± 14 days), with a peak on March 21, and 62% of the legal-sized male crabs in CMA G were soft on any given day between February 5-May 12 (± 16 days), with a peak on March 24.

Évaluation des données sur la carapace molle des crabes dormeurs (*Metacarcinus magister*) mâles de taille réglementaire dans les zones de gestion du crabe E-S, E-T, G et H en Colombie-Britannique, de 2009 à 2013

RÉSUMÉ

Le crabe dormeur (*Metacarcinus magister*) mue périodiquement pour grossir. Dans le sud de la Colombie-Britannique, au Canada, on croit que les crabes mâles de taille réglementaire (≥ 165 mm de largeur de carapace, d'une pointe à l'autre) muent généralement durant l'hiver et au printemps, bien que l'on ne connaisse pas le moment exact de cette mue et qu'il puisse être variable. Après la mue, la nouvelle carapace est molle et se durcit graduellement au cours des deux à trois mois qui suivent. Lorsqu'ils portent cette carapace molle qui leur offre une protection moindre qu'un exosquelette dur, les crabes sont plus vulnérables et risquent d'être blessés ou tués. Afin de mieux protéger les crabes mâles de taille réglementaire dans les zones de gestion du crabe (ZGC) E-S, E-T, G et H, les gestionnaires des pêches ont demandé des renseignements sur les périodes de carapace molle chez ces crabes, et sur la variabilité de ces périodes. Par conséquent, un programme de recherche collaborative a été mené de 2009 à 2013, auquel Pêches et Océans Canada (MPO) et l'industrie de la pêche au crabe ont participé. Des données biologiques sur le crabe ont été recueillies de deux façons :

1. à l'aide de casiers normalisés utilisés de façon indépendante de la pêche commerciale;
2. auprès de navires commerciaux pratiquant la pêche.

Deux méthodes d'analyse ont été utilisées :

1. évaluer la proportion de mâles de taille réglementaire à carapace molle par rapport à l'ensemble des crabes mâles de taille réglementaire prélevés;
2. évaluer le nombre de mâles de taille réglementaire à carapace molle prélevés par casier (capture par unité d'effort).

Deux modèles – un modèle proportionnel et un modèle de capture par unité d'effort (CPUE) – ont été élaborés à l'aide d'un cadre bayésien afin d'estimer la période de proportion maximale et l'abondance relative maximale, respectivement, des crabes mâles de taille réglementaire à carapace molle d'après les données observées dans le cadre des deux programmes d'échantillonnage. Les analyses ont également permis de déterminer les périodes (ainsi que d'estimer l'incertitude) où la proportion maximale et l'abondance relative maximale des mâles de taille réglementaire à carapace molle étaient de 95 %, 90 %, 85 %, 75 % et 50 %. D'après les analyses, la période de proportion et d'abondance relatives maximales de crabes mâles de taille réglementaire à carapace molle dans les quatre ZGC avait lieu du 5 au 27 mars. Selon les données du modèle proportionnel obtenues dans le cadre du programme d'échantillonnage indépendant de la pêche, et une réduction de 10 % du pic (0,90 × pic), 48 % des crabes mâles de taille réglementaire dans la ZGC H avaient une carapace molle entre le 23 janvier et le 7 mai (± 10 jours), avec un pic le 15 mars; 58 % des crabes mâles de taille réglementaire dans la ZGC E-S avaient une carapace molle entre le 15 janvier et le 10 mai (± 12 jours), avec un pic le 12 mars; 43 % des crabes mâles de taille réglementaire dans la ZGC E-T avaient une carapace molle entre le 26 janvier et le 16 mai (± 14 jours), avec un pic le 21 mars; et 62 % des crabes mâles de taille réglementaire dans la ZGC G avaient une carapace molle entre le 5 février et le 12 mai (± 16 jours), avec un pic le 24 mars.

GLOSSARY

CPUE = Catch (C) is defined as the number of soft-shell legal-sized male crabs in a trap. The CPUE is defined as the total catch divided by the total number of traps (N/T) used during a sampling event (i.e. day).

"Dseye" = the number of calendar days between September 30 and the sampling event 'i'.

DFO = Department of Fisheries and Oceans (or Fisheries and Oceans Canada).

FD = Fishery-dependent, as in fishery-dependent sampling (i.e. commercial vessel sampling).

FI = Fishery-independent, as in fishery-independent sampling (i.e. non-commercial sampling with standardized gear, bait and soak times).

IFMP = Integrated Fisheries Management Plan = document produced by DFO.

Index Areas = "clusters" of Pacific Fishery Management Area (PFMA) subareas, whose locations were selected based on high concentrations of fishing activity (as revealed by 2008 electronic monitoring).

Legal-sized male Dungeness Crab = >=165 mm notch width.

Model Year = October 1st of one year to September 30th of the following year.

N = Number of Sampling Events.

NW = Notch width = the carapace width measurement taken immediately anterior to the antermost spines, from notch to notch.

Peak Date = the date at which the model peak value estimate is reached.

Peak Value = the highest point on the modelled curve. This is either the maximum proportion or relative abundance of soft-shell legal-sized males estimated for the population.

p(coeff. for dseye >0) = estimated probability that the coefficient of the predictor variable "dseye" is larger than zero.

p(coeff. for dseye^2 >0) = estimated probability that the coefficient of the predictor variable "dseye^2" is larger than zero.

PFMA = Pacific Fisheries Management Area = DFO statistical management area. PFMA subareas are smaller subdivisions within PFMA areas.

Proportion (or PS) = the proportion of observed soft-shell legal-sized male crabs to all observed legal-sized male crabs captured from all traps during a sampling event.

R^2 = coefficient of determination. It is used to indicate how well data fit a statistical model.

Relative Abundance = Model estimated indices of absolute crab abundance (number) based on CPUE data.

Sampling Event = the time period (i.e. date(s)) when all traps were hauled and data recorded for one sampling program, in one index area. It usually represents a single day, but occasionally more than one day was required to collect sufficient catch data for a single sampling event (recorded as the first day of sampling).

S.CPUE = CPUE re-expressed (or standardized) as a fraction of the maximum CPUE observed in an index area during one year, in order to combine observed data across years.

Soft-shell period at 1.5(1)Peak – The time period when, on any given day, legal-sized male crabs are in soft-shell condition equal to, or greater than, 50% of the peak value (i.e. 1.5() × Peak value (either proportion or relative abundance)), or in other words, at a level 10% lower than the peak value).

Trap Usability Codes – Codes given to traps when hauled, indicating problems with the traps, such as holes, no bait, predators in the trap, etc.

1.5(1)Peak, 1.3(1)Peak, 1.2(1)Peak, 1.1(1)Peak and 1.0(1)Peak – 95%, 90%, 85%, 75% and 50% of the peak value, respectively (or 5%, 10%, 15%, 25% and 50% reductions of the peak value (proportion or relative abundance). The days at which these reductions from the peak value intersect the model curve are defined as the start and end dates for soft-shell periods associated with each of these reductions.

95% CI – Bayesian 95% credible intervals, with L95% = lower 95% credible interval bound (e-limit), and U95% = upper 95% credible interval bound which contain 95% of the posterior probability estimates.

1 INTRODUCTION

The Dungeness Crab (*Metacarcinus magister*)[1] is harvested coastwide in British Columbia (BC), and is an ecologically and economically important crab species for the province. The trap fishery is comprised of, and benefits, three main sectors:

1. First Nations (FN) communities harvest crabs for traditional food, social and ceremonial (FSC) purposes;
2. local and visiting recreational fishers harvest crab for personal food use and/or leisure providing potential economic benefits for charter operations and lodges; and
3. the commercial fishery provides employment for fishers and processors, and harvesting contributes millions of dollars to the provincial Gross Domestic Product (DFO 2014).

Dungeness Crabs increase in size incrementally by shedding their old shell, to uncover their new, larger shell underneath, a process called "ecdysis" (moulting). By secreting hormones, they initiate development of a new, paper-thin exoskeleton (shell) that forms beneath the old hard outer exoskeleton. The day before a crab is ready to moult, it absorbs seawater through its gut, causing the crab to swell and split the suture line, a seam located at the back of the old carapace. The crab then backs out of its old, hard exoskeleton. The new, flexible and soft exoskeleton expands by 15 to 30% and gradually hardens over a period of two to three months (Butler 1961, 1960; WDFW 2015a). During this soft-shelled period, crabs are more vulnerable to injury and/or mortality from agonistic interactions with other crabs, encounters with predators, or handling by fishers (Kruse *et al.* 1994; Tegelberg and Magoon 1971; Tegelberg 1972).

Small crabs moult more frequently than large crabs (Butler 1961). In BC, male crabs undergo approximately 10 moults, at a decelerating frequency, from the time of larval settlement until they reach sexual maturity at 100-120 mm carapace width point-to-point (PW) at approximately 2 years old. After reaching maturity, Dungeness Crabs generally moult annually. They reach a legal size of 165 mm PW (equivalent to 154 notch width (NW; Phillips and Zhang 2004)) at ~3.5-4 years old (12-14 total moults; Butler 1961). Male crabs usually only moult once more after reaching legal size, and some larger crabs skip-moult (do not moult for two years; Butler 1961).

Soft-shell crabs are crabs that recently moulted, whose shells are not fully hardened and yield to finger pressure. Muscles in soft-shell crabs are still forming to fill the new, larger shell, resulting in yields of less than 20% of their weight in meat, while fully hardened crabs yield 25% of their weight in meat (WDFD 2015a). Meat from soft-shell crabs is watery, mushy, lacking texture and of generally poor quality resulting in lower desirability for consumption or commercial sale. In BC, shell hardness is measured with a spring-driven device called a durometer. In DFO's Crab by Trap Integrated Fisheries Management Plan (IFMP), a soft-shell Dungeness Crab is legally defined as a crab with a durometer measurement of 70 units or less (DFO 2014).

The management measures for all sectors of the BC Crab by Trap fishery include commercial and area licensing, limits on numbers of traps and soak time, gear restrictions, a minimum harvestable size limit of 165 mm PW, and sex restriction, where non-retention of females is mandatory in commercial and recreational sectors. Females are also protected naturally, as their growth rates become slower than males after maturity, and they rarely reach the male legal size limit (Hankin *et al.* 1989). The minimum size limit for male crabs allows them to be sexually

[1] *Metacarcinus magister*, formally *Cancer magister*, is accepted as the current valid taxonomic name for Dungeness Crab (Davie 2015; Schram and Ng 2012).

mature for 1 to 2 years prior to becoming of legally harvestable size, thus maintaining a viable population. Consequently, all crab fisheries attempt to avoid catching female and sublegal crabs and target legal-sized males, the majority of which are harvested each year. The focus of this paper is to explore when these sought-after legal-sized male crabs are in soft-shell condition. There are various management measures that fisheries managers use to help protect soft-shell crabs in BC, such as a non-retention rule, seasonal closures, trap haul frequency restrictions, and prohibition of hanging bait. The only management measure to protect soft-shell crab that is consistent throughout the seven crab management areas (CMAs) in BC (Figure 1) is non-retention. Soft-shell crabs must be released immediately in the location where they are captured, in a manner that will cause least harm, such as releasing them into the water as close to the surface as possible (DFO 2014).

Three of the seven CMAs in BC (A in Hecate Strait/McIntyre Bay, and I and J in the Fraser River area) have seasonal closures to protect legal-sized male crabs during the vulnerable soft-shell stages of moulting. Opening and closing times for seasonal closures are set in the Crab By Trap IFMP (DFO 2014), although in CMA A there is a voluntary soft-shell sampling program paid for by industry to determine in-season timing of the annual spring moult period. Information from the soft-shell program is used by fisheries managers and industry to better understand variability in moult timing and to potentially adjust the timing of fishing seasons in CMA A.

American crab fisheries in California, Oregon, and Washington also recognize the vulnerable soft-shell periods in their management plans and have seasonal closures in place to protect moulting male crabs (Hankin *et al.* 1997). In Washington, the state closest to our study area, shell condition sampling using crab traps has been conducted since 1970 (D. Velasquez, Fish and Wildlife Biologist, WDFW, pers. comm. October 29, 2015), following a standardized procedure (WDFW 2015b). This must be conducted at multiple sampling reference stations "by a qualified fisheries biologist or staff technician that does not commercially crab". The soft-shell periods are different for crabs in the western "coastal waters" and the northern "inside waters" of Washington, and there are also separate commercial and recreational harvest periods. Fishery openings are scheduled to "occur when >80% of the legal-size crabs captured are hard-shell in the majority of years sampled" (D. Velasquez, pers. comm.; WDFW 2015b). In Alaska, there are fishery closures during most of the legal-sized male soft-shell period, and there are closures when females are soft-shelled and when mating occurs (ADFG 2015).

The remaining four CMAs in BC without soft-shell closures include B, E (referred to as CMAs E-S and E-T herein, two separately managed subareas within CMA E), G, and H (Figure 1). In CMA B, a three month (December 1 to March 1) winter closure supported by industry was implemented in 2013 to help resolve gear compliance issues. Timing of this closure was not based on existing crab biological data. Limited data have been collected from the area and, consequently, a more intensive sampling program was initiated in 2013. CMA B is not discussed further in this paper.

CMAs E-S, E-T, G, and H are open to commercial crab fishing all year. However, the frequency of hauling traps is currently reduced in the winter/spring in these CMAs to decrease harm to soft-shell legal-sized male crabs. Trap haul limits have been set to avoid daily hauling of commercial gear and is believed to reduce handling injuries and mortality (Table 1). Fisheries managers set the timing of the trap haul restrictions based on advice from industry. Managers then requested advice from the Science Branch of DFO, through the CSAS process, to determine the specific timing of legal-sized male soft-shell periods in each of these CMAs, and evaluate whether there are spatial and/or interannual variations. This will provide background knowledge to assist managers in making various types of well-informed management decisions in the future, if required. This paper serves that purpose. Consequently, in 2009, two industry-

sponsored sampling programs were initiated using different methodologies, each providing slightly different perspectives of the fishery:

a) a commercial vessel sampling program; and

b) a standardized fishery-independent sampling program.

The commercial vessel sampling program provided information on what the industry actually caught and when. The fishery-independent sampling program was added to support the commercial results, and to ensure continuous data collection throughout the year, so as to avoid data gaps, especially when commercial fishing was slow or not occurring (possibly due to soft-shell occurrence, or low catches of legal crab). The fishery-independent sampling program was also standardized to reduce the influence of different variables found within commercial crab fishing practices.

The objectives of this working paper are to:

1. Provide estimates of proportions and catch per unit effort (CPUE) of soft-shell legal-sized males from commercial vessel and standardized fishery-independent sampling programs in CMA E-S, E-T, G, and H from 2009 to 2013.
2. Fit statistical models to the sample data to determine population estimates of proportion and relative abundance (i.e. model–expected $S\text{–}CPUE$ (based on observed S-CPUE data)) of soft-shell legal-sized male crabs, including estimates of uncertainty.
3. In the form of decision tables, provide population estimates and timing of peak soft-shell proportion and relative abundance.
4. Discuss sources of uncertainty of this assessment, including the sampling program and data limitations.

2 METHODS

2.1 CRAB BIOLOGICAL DATA COLLECTION

2.1.1 Overview

This research program was conducted from January, 2009 to December, 2013 with scheduled data collection of all sizes and sexes of Dungeness Crab. Two sampling programs were used, each with different fishing methodologies:

1. a commercial vessel sampling program (fishery-dependent, FD); and
2. a standardized, fishery-independent sampling program (FI).

Research was conducted in CMAs E-S, E-T, G and H (Figure 1) at seven survey locations (termed "index areas"), with a third party service provider hired by industry performing all field work and data collection.

2.1.2 Sampling Programs

2.1.2.1 Standardized Fishery-Independent (FI) Sampling Program

Service providers were required to collect crab biological data independent of the commercial fleet on a regular sampling schedule (see section 2.1.4). They used their own boats and set their own standardized traps in index areas, following specific sampling procedures outlined by DFO in the Crab by Trap IFMP. Standardized trap fishing was defined as:

- commercial style circular stainless traps 90 cm (36 in) diameter by 26 cm (10 in) high with two opposing tunnels, each with a single set of triggers. Frames were steel, rubber wrapped on the bottom ring, and covered by stainless steel mesh with approximately 6 cm (2½ in) squares or diamonds;
- existing escape ports were closed off with rot cord in order to collect all size ranges of crab;
- bait was always two large herring, torn in half and placed in a 500 ml bait jar with small (one mm in diameter) holes in the lid and sides. The bait jar was suspended in the center of the trap, not touching the ground; and
- traps were soaked overnight, between 16 and 28 hours, as close to 24 hours as possible.

2.1.2.2 Fishery-Dependent (FD) Sampling Program

Service providers were also hired to opportunistically collect crab biological data from commercial vessels fishing in index areas on a regular sampling schedule (see section 2.1.4). Commercial fishing practices are somewhat varied because of flexibility in gear restrictions as outlined in the Crab By Trap IFMP (DFO 2014). Specifically, commercial crab fishers:

- may use different sizes and types of traps, up to a limit;
- must have escape ports of regulation size in their traps to allow small crabs to escape;
- may use a variety of bait types;
- may soak their traps for up to a maximum 18 days.

Note that the aim of the study design was meant not to compare results between the FI and FD sampling program results, but rather for the two sampling programs to supplement each other, especially during time periods when commercial fishers were not fishing.

2.1.3 Survey Locations

Service providers were required to regularly collect crab biological data for the FI and FD sampling programs in seven index areas (Figure 2) located in four CMAs: CMA H (Nanaimo, Ganges, Sidney; Figure 3), CMA E-S (Sooke; Figure 4), CMA E-T (Tofino; Figure 4), and CMA G (Retreat Passage, Village Channel; Figure 5). Index areas were comprised of clusters of Pacific Fishery Management Area (PFMA) subareas (Table 2) whose locations were primarily selected based on high concentrations of fishing activity as revealed by 2008 electronic monitoring of the fleet. Another consideration for index area selection was ease of accessibility for service providers. Index areas were made sufficiently large to allow service providers some freedom to choose where they fished so they could successfully obtain the required sample size of crabs. Furthermore, in CMA H, in order to adequately represent perceived variability in crab populations in the spatially large management area, the three index areas were spread out to the north and south. Prior to 2009, service providers opportunistically collected crab biological data from commercial vessels fishing anywhere in CMAs, however, this approach often proved to be unsuccessful. Many sampling opportunities were missed as the service providers were unable to find commercial vessels. Starting in 2009, sampling was focused in index areas, which helped service providers find vessels and made sampling more efficient.

2.1.4 Data Collection

Data collection began in January, 2009 (January 2010 for the Retreat Passage Index Area), and finished in December, 2013. Sampling events (i.e. dates or time periods when traps were hauled and data were recorded for one sampling program, in one index area) were scheduled to

occur 18 times per year at each index area, for each of the FI and FD sampling programs, with targets of twice a month from January to June (12 sampling events, spaced approximately 15 days apart), and once per month from July to December (6 sampling events, spaced approximately 30 days apart). More frequent sampling from January to June was attempted in order to obtain fine-scale temporal resolution during the winter/spring period when males are believed to moult. Each sampling event usually represented a single day, but occasionally more than one day was required to collect sufficient catch data. In these cases, data were combined, counted as a single sampling event, and named as the first date of collection.

The number of sets sampled per day varied with the sampling program and was dependent on the total number of crabs caught. Service providers were required to record data for a minimum sample size of 200 crabs (both sexes and all sizes) per sampling event. In the FI program, service providers had to respect any commercial crab fishing closures (except Nanaimo Harbour) in index area subareas as outlined in the Crab by Trap IFMP (DFO 2014). The service providers were otherwise free to fish anywhere within the index area, and locations were not necessarily consistent for each sampling event, or with FD fishing locations. They were encouraged to collect crabs from at least 20 standardized traps set on two strings in each index area. In the FD program, service providers were encouraged to collect crabs from at least 20 traps set on four different strings in each index area, and collect crabs from different vessels, if possible. The minimum sample size per vessel was 50 crabs.

For both programs, measurements were required for all crabs observed in sampled traps. Data recorded for each crab sampled included: date of trap haul, set and trap number, trap soak time, trap usability code (indicating whether there were problems with the trap), crab species, carapace notch width (NW), sex, and shell condition. Shell condition codes represent 8 stages of shell condition or "hardness", from the very soft shell condition of a freshly moulted crab (0 to 6 days) to the very hard and older shell condition (more than 24 months since last moulting; Table 3). Any injuries and mating marks were also recorded, but were not used in the analysis.

2.2 DATA ANALYSIS

2.2.1 Data Checks and Exclusions

Data for crab species other than Dungeness Crab were excluded from the analyses. Empty traps with no indications of fishing problems were included in the analysis, as well as traps that caught other crab species, but no Dungeness Crab. For both programs, traps with conditions that may have affected their catchability, as indicated by trap "usability codes" (e.g. hole in trap, predator in trap, etc.), were excluded from analyses. In addition, traps from the FI sampling program (only) that soaked less than 16 hours or longer than 28 hours were also excluded from analyses in order to keep the data standardized.

Based on shell condition codes (Table 3), crab data were divided into two groups, a "soft-shell" group consisting of shell condition codes 2, 3, 4 and 5 (moulted 0 days to 3 months ago), and a "hard shell" group consisting of shell codes 1, 6, 7 and 8 (moulted anytime from 3 to >24 months ago).

Two methods for analyzing FI and FD soft-shell legal-sized male crab data were used:

a) proportion of soft-shell legal-sized male crabs of all legal-sized male crabs, and

b) catch per unit of effort (CPUE) of soft-shell legal-sized male crabs.

The proportion analysis provides an assessment of the abundance of soft-shell legal-sized male crabs relative to the abundance of hard legal-sized male crabs. The CPUE analysis takes into account sample size, but may be influenced by variable densities. CPUE is a better indicator of

how many soft-shell legal-sized male crabs could be caught per trap during a certain time period while the proportion of soft-shell individuals better represents the timing when legal-sized male crabs are soft. Therefore, for each CMA (as a whole) and for each index area, four analyses were performed (i.e. proportion and CPUE analysis methods applied to each of the FI and FD sampling programs).

2.2.2 Proportion Data

The term "proportion" (PS) used in this document is defined as "the proportion of observed soft-shell legal-sized male crabs to all observed legal-sized male crabs captured from all traps during a sampling event. It was calculated by pooling catches from all traps:

$$PS = \frac{N_{soft}}{N_{soft} + N_{hard}} \quad (1)$$

where N_{soft} and N_{hard} are the total number of soft-shell and hard-shell crabs, respectively, captured in a sampling event.

Standard errors for the proportion were calculated as:

$$SE = \sqrt{\frac{PS\,(1-PS)}{N_{soft} + N_{hard}}} \quad (2)$$

2.2.3 CPUE Data

Catch (C) is defined as the number soft-shell legal-sized male crabs in a trap. The CPUE is defined as the total catch divided by the total number of traps (NT) used during a sampling event (i.e. day):

$$CPUE = \frac{\sum_{SameSampEvent} C_i}{NT} \quad (3)$$

$CPUE$ was used as a proxy indicator of abundance of soft-shell legal-sized male crabs in the population. To assess variations in catch rates (catches per trap) among individual traps, we also calculated corresponding standard errors (Zar 1984):

$$SE_u = \sqrt{\frac{\sum_{SameSampEvent} (C_i - CPUE)^2}{NT(NT-1)}} \quad (4)$$

2.2.4 Graphs of Observed Proportion and CPUE Data

The first objective of the working paper was to provide estimates of proportions and CPUE of soft-shell legal-sized males from the FI and FD sampling programs in CMAs E-S, E-T, G and H from 2009 to 2013. The results were presented as graphs of the data for each of the five years. The observed data were analyzed separately for each of the seven index areas, and were combined and analyzed accordingly for each of the four CMAs, for each sampling program. However, FI data were usually collected on different days than FD data within each index area, and data were usually collected on different days among index areas within CMAs, making it difficult to plot a mean line through the observed data points for a CMA as a whole for five

individual years. Regression lines did not fit properly over five years of data, and automated 'moving average' lines did not produce reasonable results. Consequently, mean lines were produced for a CMA as a whole by combining any data points (i.e. sampling events) from all index areas within that CMA and sampling program that were within 4 days of each other and calculating mean data points. Therefore, each "mean" point was calculated from one to three sampling events, each from different index areas.

2.2.5 Bayesian Models

The second objective of the working paper was to fit statistical models to the data. Two models, a proportion model and a CPUE model, were developed within a Bayesian framework to estimate the timing of peak proportion and the peak relative abundance (i.e. model–expected $S\text{–}C\overline{PUE}$ (based on observed S-CPUE data)), respectively, of soft-shell legal-sized male crabs based on observed data from the two sampling programs.

Although the sampling programs started in January (2009) and finished in December (2013), the model was not created for a standard calendar year. This is because we knew that catches of soft-shell legal-sized males were generally higher in the spring and lower in the early fall, and that soft-shell legal-sized male catches in the late fall usually increased into the following calendar year. We felt this typical increase of soft-shell legal-sized male in the late fall was important and potentially represented the left side of the model curve, and would be lost in a January to December model. Accordingly, the model was created for a "model year", defined as October 1st of one year to September 30th of the following year. Our model year naming convention uses the year of the January data, thereby representing the year the majority of sampling events occurred. For example, model year 2010 is defined as October 1st, 2009 to September 30th, 2010. Note that because the sampling programs began in January, 2009, no data were available for October to December, 2008 for the 2009 model year.

Models were created for all index areas (combined) within each CMA. Data from Nanaimo, Ganges, and Sidney Index Areas were combined for CMA H, and Village Channel and Retreat Passage Index Areas were combined for CMA G. CMAs E-S and E-T are represented by one index area each (Sooke and Tofino, respectively), and although they are actually "sub-CMAs" of CMA E, fisheries management manages them separately. Therefore they were analyzed individually.

Models were also run for each index area individually within CMAs H and G, to assess spatial variability within each CMA. However, very few sampling events occurred in the FD sampling program in either index area in CMA G, so these results are incomplete and are not included.

Finally, the proportion model was run for FI data for each individual model year for CMA H (all index areas combined), E-S, E-T, and G (both index areas combined) to examine interannual variability.

2.2.5.1 Proportion of Soft-shell Crab

A generalized linear model with a binomial distribution was applied to model the proportion of soft-shell crabs. The model was constructed with a hierarchical structure when data from multiple years were used simultaneously.

Single Year

The proportion of soft-shell crabs was modelled using a binomial probability distribution:

$$S_t \sim dbinom\ (P_t, N_t) \tag{5}$$

where S and N refer to the number of soft-shell crab and total number of crab captured in a sampling event, respectively, P is the proportion of soft-shell crab in the population, and the subscript, t, denotes the sampling event. The population proportion, P, was assumed to be a function of the number of days (δ) between September 30 (representing Day 0) and the sampling event t through the Logit link function, and a random effect was added to the function to model overdispersion and form a Bayesian version of quasibinomial distribution model (Lunn *et al.* 2013):

$$\text{logit}(P_t) = \alpha 1 + \alpha 2 \times \delta_t + \alpha 3 \times \delta_t^2 + r_t \quad (6)$$

where $\alpha 1$, $\alpha 2$, and $\alpha 3$ are model parameters, and r_t is a variate from a normal distribution with a mean of zero and a variance of σ_r^2 which is a model parameter. δ was used as a predictor variable in the function because we want to examine how P varies (or changes) with days. Plots of P against δ showed that P, in general, first increased with δ in the early part of a modelling year, and then decreased as δ further increased. We therefore included δ^2 in the function to model this quadratic effect of δ on P. If less than 5% or more than 95% of the estimates of $\alpha 2$ are above zero, δ is regarded as having a significant effect on P, or simply being significant. Similarly, if less than 5% or more than 95% of the estimates of $\alpha 3$ are above zero, δ^2 is regarded as being significant. In the tables, we refer to these as "p(coef. for days >0)" and "p(coef. for days^2 >0)".

The expected proportion of soft-shell individuals for any given day of a model year was calculated as:

$$\hat{P}_d = \frac{\exp\left(\alpha 1 + \alpha 2 \times \delta_d + \alpha 3 \times \delta_d^2\right)}{1 + \exp\left(\alpha 1 + \alpha 2 \times \delta_d + \alpha 3 \times \delta_d^2\right)} \quad (7)$$

where the subscript, d, denotes a calendar day within the model year.

In some cases, proportions of soft-shell crab in catches exhibited a bimodal distribution. In these cases, the number of days (τ) between September 30 and a transition day between the two modes was also used in the regression for $\text{logit}(P_t)$:

$$\text{logit}(P_t) = \alpha 1 + \alpha 2 \times \delta_t + \alpha 3 \times \delta_t^2 + I_t\left(\alpha 4(\delta_t - \tau) + \alpha 5(\delta_t - \tau)^2\right) + r_t \quad (8)$$

where $\alpha 1$, $\alpha 2$, $\alpha 3$, $\alpha 4$, $\alpha 5$, and τ are model parameters, and I is an identification parameter that is set to 1 if $\delta_t > \tau$ or 0 otherwise, and r_t is, as above, a variate from a normal distribution.

The expected proportion for any given day of a model year was calculated as:

$$\hat{P}_d = \frac{\exp\left(\alpha 1 + \alpha 2 \times \delta_d + \alpha 3 \times \delta_d^2 + I_d\left(\alpha 4(\delta_d - \tau) + \alpha 5(\delta_d - \tau)^2\right)\right)}{1 + \exp\left(\alpha 1 + \alpha 2 \times \delta_d + \alpha 3 \times \delta_d^2 + I_d\left(\alpha 4(\delta_d - \tau) + \alpha 5(\delta_d - \tau)^2\right)\right)} \quad (9)$$

Multiple Years

The proportion of soft-shell crab at a sampling event t in year y was modelled using a binomial probability distribution:

$$S_{y,t} \sim dbinom(P_{y,t}, N_{y,t}) \tag{10}$$

$\text{logit}(P_{y,t})$ was similarly modelled as Eq. 6, but a process error was added for each year:

$$\begin{cases} \text{logit}(P_{y,t}) = \text{logit}(P_t) + \phi_y \\ \text{logit}(P_t) = \alpha 1 + \alpha 2 \times \delta_t + \alpha 3 \times \delta_t^2 \end{cases} \tag{11}$$

where P_t indicates the expected mean proportion of soft-shell legal-sized male crabs in the population at the sampling event t, and ϕ is a random process error which has a normal probability distribution with a mean 0 and variance σ_p^2, which is a model parameter. To model proportions for a CMA containing data from more than one index area, data collected in the same year from different index areas were combined for the analysis. R^2 was calculated as:

$$1 - \sum_{y,t}\left(\frac{S_{y,t}}{N_{y,t}} - P_{y,t}\right)^2 \Big/ \sum_{y,t}\left(\frac{S_{y,t}}{N_{y,t}} - mean\left(\frac{S_{y,t}}{N_{y,t}}\right)\right)^2 \tag{12}$$

The expected proportion for any given day was calculated using Eq. 7.

2.2.5.2 Relative Abundance of Soft-shell Crab

The overall abundance of soft-shell legal-sized male crabs in all the survey areas was expected to vary each year. In order to combine these data across years, it was necessary to standardize them to a common baseline. This was done by re-expressing each CPUE datum ($CPUE$) as a fraction of the maximum CPUE ($CPUE_y^{max}$) observed in that index area during that year:

$$S\text{-}CPUE_t = \frac{CPUE_t}{CPUE_y^{max}} \tag{13}$$

$S\text{-}CPUE$ among different years are, therefore, more comparable than $CPUE$, as variations in annual abundance are incorporated in their calculation. $S\text{-}CPUE$ values range between 0 and 1. To convert these values to the real line in order to apply a normal probability distribution in the modelling process, $S\text{-}CPUE$ were transferred using the complementary log-log (clog-log) function:

$$CLSU_t = \log\left(-\log(1 - S\text{-}CPUE_t\right) \tag{14}$$

We fitted models to $CLSU$ values to estimate expected $S\text{-}CPUE$, and this model-expected $S\text{-}CPUE$ ($S\text{-}\hat{CPUE}$) is defined in this paper as the relative abundance of soft-shell crab.

Multiple Years

$CLSU$ at a sampling event t in year y was modelled using a normal probability distribution:

$$CLSU_{y,t} \sim dnorm(\hat{CLSU}_{y,t}, \sigma^2) \tag{15}$$

where the variance, σ^2, is a model parameter, and $\hat{CLSU}$ is the model-expected ctog-log transformed value for $S\text{-}CPUE$. $\hat{CLSU}$ was assumed to be a function of the number of days (δ) between September 30 and the sampling event t in a hierarchical structure:

$$\begin{cases} \hat{CLSU}_{y,t} = \hat{CLSU}_t + \varepsilon_y \\ \hat{CLSU}_t = \beta 1 + \beta 2 \times \delta_t + \beta 3 \times \delta_t^2 \end{cases} \quad (16)$$

where $\beta 1$, $\beta 2$, and $\beta 3$ are model parameters, the subscript y denotes year, and ε is a random process error, which has a normal distribution with a mean of zero and variance σ_ε^2, which is a model parameter. If less than 5% or larger than 95% of estimates of $\beta 2$ are above zero, δ is regarded as being significant. Similarly, if less than 5% or larger than 95% of estimates of $\beta 3$ are above zero, δ^2 is regarded as being significant.

The expected S-CPUE for sampling event t in year y was calculated as:

$$\hat{S\text{-}CPUE}_{y,t} = 1 - \exp\left(-\exp(\hat{CLSU}_{y,t})\right) \quad (17)$$

R^2 was calculated as: $1 - \sum_{y,t}\left(S\text{-}CPUE_{y,t} - \hat{S\text{-}CPUE}_{y,t}\right)^2 \Big/ \sum_{y,t}\left(S\text{-}CPUE_{y,t} - mean(S\text{-}CPUE_{y,t})\right)^2$.

The expected S-CPUE, for any given day of a model year was calculated as:

$$\hat{S\text{-}CPUE}_d = 1 - \exp\left(-\exp(\beta 1 + \beta 2 \cdot \delta_d + \beta 3 \cdot \delta_d^2)\right) \quad (18)$$

2.2.5.3 Model Execution

The models were fitted using the WinBUGS software (Spiegelhalter *et al.* 2003) with a Bayesian approach. Uninformative priors were assigned to all the model parameters except for τ. $\alpha 1$, $\alpha 2$, $\alpha 3$, $\alpha 4$, $\alpha 5$, $\beta 1$, $\beta 2$, $\beta 3$ were each assigned a normal distribution with large variance: $N(0, 100^2)$; precisions (the reciprocal of variance) $1/\sigma^2$, $1/\sigma_\varepsilon^2$, $1/\sigma_\alpha^2$, and $1/\sigma_\tau^2$, were all assigned a gamma distribution with a shape parameter of 0.01 and a rate parameter of 0.01: $\gamma(0.001, 0.001)$; τ was provided with rather informative normal distributions to handle the bimodal structure. The mean of such a normal distribution was set to be the number of days between September 30 and the day the lowest proportion was observed in the catch between the two modes, and the coefficient of variation was set to be 5%.

The first 10,000 iterations from a Markov chain were treated as a burn-in period and discarded. Thereafter, 10,000 iterations with a thinning interval of 100 iterations were saved and used for subsequent analyses. Two chains were used with different initial values for the convergence test by the Gelman-Rubin diagnostic (Gelman and Rubin 1992). Evidence of convergence was warranted when the ratio of the pooled posterior variance to the average within-sample variance approached one.

2.2.5.4 Model Outputs

Tables with the following key parameters are presented to describe and compare all model outputs:

Peak Value - the highest point on the modelled curve (Figure 6a). This is the maximum proportion or relative abundance of soft-shell legal-sized males. The 95% credible interval (CI) associated with the peak value represents the uncertainty above and below the peak value;

Peak Date – the date at which the peak value is reached. The 95% CI associated with the peak date indicates the estimated date has a 95% probability of occurring within this CI;

Soft-shell Periods (at specific levels below the peak value) - the time period when the proportion or relative abundance is at least, or above, a (specific) reduced level from the peak value on any given day. For each model outcome, soft-shell periods are presented in tables that correspond to five, arbitrarily chosen, reduction levels from the peak value, with 95% CI around their start and end dates. Chosen reductions correspond to 95% ("0.95*Peak"), 90% ("0.90*Peak"), 85% ("0.85*Peak"), 75% ("0.75*Peak"), and 50% ("0.50*Peak") of the peak value (i.e. a 5%, 10%, 15%, 25% and 50% reduction from peak values; Figure 6a). The dates at which these reductions horizontally intersect the model curve (corresponding to dates on the x-axis ('Time of Year')) are defined as the start and end dates for soft-shell periods associated with the reduction levels. For example, if a peak proportion of 0.50 soft-shell legal-sized male crabs occurred on peak date March 15 in a given CMA (as determined from the model), then the 10% reduction from the peak value would be 0.45 (0.90 * 0.50). The corresponding soft-shell period would be those dates during the model year, between which, on any given day, the proportion of soft-shell legal-sized male crabs was at least 45%. This interval is defined as the "soft-shell period at 0.90*Peak". These five reduction levels were chosen arbitrarily, but produce soft-shell periods of less than, and more than, 3 months, the approximate length of time that a crab transforms from a freshly moulted crab to a "new hard-shell" crab of shell condition 1 (Butler 1961;Table 3). Three months is also the length of time the trap haul restrictions are in place (Table 1). Although the reduction levels from the peak cover a wide range (95% to 50%), for most model outputs, small incremental reductions from the peak can produce large changes in estimated soft-shell periods. Also note any other reductions can be calculated if required, such as, for example, 0.98, 0.70, or 0.40 of the peak. For brevity in the paper, focus is on the 10% reduction (0.90*Peak) for comparisons, as many (but not all) of the models produced soft-shell periods around 90 days (3 months), but all five reduction scenarios are reported in the tables.

Note that the uncertainties around each of the start and end dates (i.e. 95% CI) are not independent of each other. Start and end dates for a soft-shell period at a specific reduction level from the peak may shift earlier or later by a maximum amount determined by the 95% CIs (Figure 6b), but the length of the soft-shell period will remain constant. In the example provided (Figure 6b), the soft-shell period has been shifted to start and end earlier (ii) and shifted to start and end later (iii). The start date could be shifted to any point within the 95% CI, but the ending date must shift accordingly, so that the length remains constant.

3 RESULTS

3.1 DATA COLLECTION SUMMARY

Over 2009 to 2013, more than 156,642 Dungeness Crabs were measured for the two sampling programs (96,896 FI and 60,746 FD) and used in the analyses, of which 18,224 were soft-shell legal-sized males and 27,945 were hard-shell legal-sized male crabs, sampled from 19,742

traps over 820 sampling events (Table 4). Although more measurements were recorded, data from many traps could not be used. If problems were noted for the traps themselves (e.g. had a hole, was not closed, had no bait, etc.), if potential predators were in the traps, or if there is any other potential influence in the trap (e.g. a starfish is smothering the bait, reducing the attraction), data from those traps were not used.

The service providers were not able to meet the sampling requirements (see Methods) equally at all index areas or in all years (Table 5 and Figure 7 to 9). The consistency of sampling frequency was good for 2009 and better for 2010, but diminished in 2011 and 2012, particularly for the FD program. Sampling frequency improved in 2013. CMA G in particular had the poorest sampling compliance (Table 5) of all areas, especially for the FD program (the lowest sample rate was 0 out of 18 required samples). Note sampling in CMA G began in 2009 at two index areas, Malcolm Island and Village Channel, but due to low FD catches, was halted at Malcolm Island and switched to Retreat Passage in 2010. Sampling at Malcolm Island did not commence until late March, 2009, and these data are therefore considered incomplete and not included in the analysis.

Traps from the FI sampling program (only) required standardized soak times between 16 and 28 hrs. Very few FI traps had soak times outside of this range (Figure 10 to 12), but those that did were excluded from analyses.

3.2 STRUCTURE OF THE RESULTS SECTION

This is a complex paper with many levels and combinations of analysis, with seven index areas within four CMAs, from two sampling programs with five years of data, and analyzed using two analysis methods. In addition, both observed results and model results are presented. The following is an explanation of the structure of the results section.

The first level of analysis is by CMA. CMA H is presented first as it had the highest frequency of sampling, followed by CMA E-S, E-T, then CMA G, which had the lowest sampling frequency. The next level of analysis is by index area within each CMA. Within CMA H, results are presented and contrasted between the three index areas (Nanaimo, Ganges and Sidney) in an appendix. Results for CMAs E-S and E-T are presented slightly differently, as they are "sub-CMAs" of CMA E. They are managed separately by fishery managers (Table 1), and are therefore presented separately (i.e. there is no analysis for CMA E as a whole). They are represented by only one index area each, so the analyses for these locations are presented similar to the index area level of analysis. Finally, the results for CMA G are presented for the CMA as a whole, and then by individual index areas. However, sampling frequency from the FD sampling program in CMA G was very low and inconsistent (Table 5); the data are therefore unusable at the index area level. Results for the FI sampling program only are presented in an appendix for CMA G.

For each CMA section, results for soft-shell legal-sized male crabs using two analysis methods (proportion and CPUE) for each sampling program (FI and FD) are presented separately in the following four sections:

1. Proportions - FI Sampling Program
2. Proportions - FD Sampling Program
3. CPUE - FI Sampling Program
4. CPUE - FD Sampling Program

Within each of these four sections, graphs of the:

(i) sample (observed) data, and

(ii) output results (graphs and "decision" tables) from the corresponding models

are presented. Note that the decision tables present various options for managers at five different reduction levels from the peak. Other levels of reduction from the peak can be considered. For easier recognition, peak results are highlighted in orange for tables of proportional analyses and in green in tables of CPUE analyses.

Model results presented in the paper were from model runs with predictor variables "days" and "days^{2}" having significant impacts (p<cutoff for days=0) ±0.05 or ±0.95), unless otherwise specified in figure and table captions. Soft-shell periods presented in this section are 10% reductions from the peak values (0.90*Peak), results for other reduction levels are presented in the tables.

3.3 CRAB MANAGEMENT AREA H

3.3.1 Proportions from FI Sampling Program – CMA H

3.3.1.1 Sample Data

The observed data from the FI sampling program in CMA H (Nanaimo, Georgia and Sidney Index Area data combined) reveal peak proportions of soft-shell legal-sized male crabs (of all legal-size male crabs) occurred in the late winter-early spring in all years 2009 to 2013 (Figure 13a, blue line). There was also a high proportion of soft-shell legal-sized males observed in the summer of 2009 and in the fall of 2012.

3.3.1.2 Model Results

The proportion model using the FI observed data for all years combined (i.e. Figure 13a, blue), estimated a peak proportion (0.54 ± 0.16) of soft-shell legal-sized males on March 15 (± 5 days, R^2=0.4082, n=242, Table 6, Figure 14a). On any given day between January 23 and May 7 (105 days, at reduction level 0.90*Peak) at least 48% (± 15%) of legal-sized male crabs were soft-shelled. Time periods for other reduction levels are listed in Table 6.

3.3.2 Proportions from FD Sampling Program – CMA H

3.3.2.1 Sample Data

The observed data from the FD sampling program in CMA H (Nanaimo, Georgia and Sidney Index Area data combined) show peak proportions of soft-shell legal-sized male crabs (of all legal-size male crabs) also occurred in the late winter-early spring in all years (Figure 13b, red line). There was also a high mean proportion in the summer of 2009 and possibly in the fall of 2012. Despite many missing FD sampling events (especially in 2012, Table 5), and some variability in proportions between individual index areas within sampling programs (especially in 2013), the FD mean peak proportions (Figure 13b) appear similar to the FI mean peak proportions (Figure 13a) in timing and magnitude within each year.

3.3.2.2 Model Results

The proportion model using the FD data for all years combined, estimated a peak proportion (0.49 ± 0.12) of soft-shell legal-sized males on March 5 (± 6 days, R^2=0.4098, n=154, Table 7, Figure 14b). On any given day between January 6 and May 4 (119 days, at 0.90*Peak), at least 44% (± 11%) of legal-sized male crabs were soft-shelled. Time periods for other reduction levels are listed in Table 7.

3.3.3 CPUE from FI Sampling Program – CMA 10

3.3.3.1 Sample Data

The observed catch per unit of effort (CPUE, crabs/trap) estimates from the FI sampling program in CMA 10 show the peak CPUE of soft-shell legal-sized male crabs occurred in the late winter-early spring for 2010 to 2013 (Figure 10a). In 2009, the peak CPUE occurred in the summer (mid-July to late August), and there was a secondary peak in the late winter-early spring. In 2013, there was a secondary peak in the fall that was almost the same magnitude as the main peak seen earlier in the year.

3.3.3.2 Model Results

The CPUE model using FI standardized CPUE data for all years combined, estimated soft-shell legal-sized male crabs reached a peak (3.44 ± 3.22) on March 27 (± 19 days, R^2=0.1117, n=242, Table 8, Figure 10a). On any given day between February 19 and May 3 (74 days, Table 8), the relative abundance of soft-shell legal-sized male crabs was equal to, or greater than, 90% of the highest relative abundance of soft-shell legal-sized male crabs over the model year. Time periods for other reduction levels are listed in Table 8.

3.3.4 CPUE from FD Sampling Program – CMA 10

3.3.4.1 Sample Data

Many FD sampling events were missed in early 2009, and in 2011 and 2012 in CMA 10 (Table 5). However, it appears from the observed CPUE from the FD sampling program (Figure 10b), the peak CPUE of soft-shell legal-sized male crabs occurred in the late winter-early spring, in 2010 to 2013. The FD mean CPUE line does not indicate a distinct peak in 2009, but rather variation in CPUE, ranging between 1.0 and 2.5 crabs/trap from mid-March to early November.

3.3.4.2 Model Results

The CPUE model using FD standardized CPUE data for all years combined, estimated soft-shell legal-sized male crabs reached a peak (0.50 ± 0.35) on March 19 (± 21 days, R^2=0.2112, n=164, Table 9, Figure 10b). On any given day between February 5 and April 27 (82 days, Table 9), the relative abundance of soft-shell legal-sized male crabs was equal to, or greater than, 90% of the highest relative abundance of soft-shell legal-sized male crabs over the model year. However, the data points are quite dispersed and the model's CIs are wider than the other models, indicating a higher level of uncertainty around the estimates. Time periods for other reduction levels are listed in Table 9.

3.3.5 Comparisons between FI and FD Sampling Programs and Analysis Methods – CMA 10

3.3.5.1 Sample Data

Sampling was more complete in the FI program (242 sampling events, versus 164 sampling events in the FD program).

Despite missing sampling events and some variation in proportions among individual mike areas within sampling programs, the FI and FD mean proportions appear similar in timing and magnitude within each year (Figure 10a and Figure 10b, respectively).

Soft-shell legal-sized male CPUE calculated from the FD sample data were at least twice as high as those calculated from the FI sample data.

3.3.5.2 Model Results

This section summarizes the key model results for CMA H presented in previous sections, and compares them between data analysis methods (proportion versus CPUE) and sampling programs (FI versus FD) (Table 10).

The date of the peak was about 11 days later with the FI sampling program compared with FD sampling program, for both the proportion and CPUE analysis methods (Table 10, Figure 17a).

At a 10% reduction from the peak (0.90*Peak), the proportion model produced a longer soft-shell period with the FD data than with the FI data (Figure 17b). The flatter shape of the proportion model curve from the FD sampling program (Figure 14b) as compared to the FI sampling program (Figure 14a) explains the 14 day longer FD soft-shell period. The FD CPUE model also produced a longer soft-shell period than the FI CPUE model, but only by 8 days (Figure 17b).

Overall, the start dates for the soft-shell period using 0.90*Peak were more variable than the end dates for both sampling programs and analysis methods (Figure 17b).

The proportion analysis method produced smaller 95% CIs around the start and end dates, compared with the CPUE analysis method (Figure 17b).

3.3.6 Comparisons Among Index Areas Within CMA H

The focus of this paper is on describing the soft-shell timing of legal-sized male crabs within CMAs, i.e. integrating across years (2009 to 2013) and index areas within CMAs. However, we present here a brief description of the results from the FI and FD sampling programs and the proportion and CPUE analysis methods as guidance to the spatial variability that might be expected at sub-CMA scales. Note that the low sample sizes for some index areas and some years increases the uncertainty of these results, as compared to the combined data for the CMA.

Results of the analyses for the two sampling programs and the two analysis methods by index area (Nanaimo, Ganges and Sidney) within CMA H are presented in Appendix A (Tables A1-A4; Figures A1-A6).

Although there were some large data gaps for 2011 and especially 2012 (Table 5), the observed FI and FD proportions within each index area (Figure A1, blue and red lines, respectively) had similar peak timing and magnitudes for all years, especially in 2010, 2011 and 2012, (except for Ganges in 2011), and were similar in timing amongst the three index areas. There was more variability between the sampling programs and index areas in 2009 and 2013.

The proportion model using FI data produced peaks similar in timing amongst all three index areas (March 12 to 17; Figure A2; Table A1). However, the soft-shell period at the 0.90*Peak level was almost 30 days longer in the Ganges Index Area (123 days) than in the Nanaimo or Sidney Index Areas (approximately 94 days; Table A1).

The proportion model using the FD data also produced peaks similar in timing amongst all three index areas (March 1 to 9; Figure A3; Table A2). The soft-shell period at the 0.90*Peak level in Sidney was about 2.5 weeks shorter (111 days) than in Nanaimo or Ganges (~129 days; Table A2).

The observed FI and FD CPUE within each index area (Figure A4, blue and red lines, respectively) were not as similar to each other as the FI and FD proportions, and there was variation between the index areas. The peak timings in any particular year were often variable between the two programs, although the peaks were generally all in the late winter-early spring

in all index areas, except in 2009. The magnitudes were usually significantly higher for the FD CPUE than the FI CPUE. The FD data had many missing data points, especially for 2011 and 2012.

The CPUE model using the FI data produced more variable results compared with the proportion model (Figure A5; Table A3). Peak timing was variable among the index areas as well, ranging from March 12 in Nanaimo to April 17 in Ganges, and Sidney in between at March 25. The soft-shell periods at the 0.90*Peak level were shorter (69 to 86 days) than those defined from the proportion method, but with higher variability in the start and end dates. Nanaimo and Ganges were most dissimilar in peak, start and end dates (Table A3).

The CPUE model using the FD data produced similar peak dates for Ganges and Sidney (March 14 and 17), whereas the predictable variables "days" and "days^2" were not significant for Nanaimo (Figure A6; Table A4). Start and end dates of the soft-shell period at 0.90*Peak were also similar for Ganges and Sidney (February 7 to late April; Table A4).

3.4 CRAB MANAGEMENT AREA E-S (SOOKE INDEX AREA)

3.4.1 Proportions from FI Sampling Program – CMA E-S

3.4.1.1 Sample Data

The observed data from the FI sampling program in CMA E-S reveal peak proportions of soft-shell legal-sized male crabs occurred in the late winter-early spring in all years 2009 to 2013 (Figure 18a, blue), although there were several missing sampling events in 2011 and 2012 (Table 5). There was also a high proportion of soft-shell legal-sized males observed in the summers of 2010 and 2013.

3.4.1.2 Model Results

The proportion model using the FI data for all years combined, estimated a peak proportion (0.65 ± 0.11) of soft-shell legal-sized males on March 12 (± 9 days, R^2=0.4427, n=70, Table 11; Figure 19a). On any given day between January 15 and May 10 (116 days, at the 0.90*Peak level) at least 58% (± 10%) of legal-sized male crabs were soft-shelled. Time periods for other reduction levels are listed in Table 11.

3.4.2 Proportions from FD Sampling Program – CMA E-S

3.4.2.1 Sample Data

There were many missed sampling events in the FD sampling program in CMA E-S over the course of the study (Table 5). However, from the observed data available, it appears the FD peak proportions of soft-shell legal-sized male crabs were similar in timing to the FI peaks, occurring from mid-winter to early spring in all years 2009 to 2013 (Figure 18b, red). The missing sampling events make it difficult to determine if there were additional peaks at other times of the year, but it appears there were possibly high proportions of soft-shell legal-sized males in the summer-fall for every year except 2012.

3.4.2.2 Model Results

The proportion model using the FD data for all years combined, estimated a peak proportion (0.59 ± 0.09) of soft-shell legal-sized males on March 9 (± 10 days, R^2=0.2591, n=54, Table 12; Figure 19b). On any given day between December 30 and May 19 (141 days, at 0.90*Peak) at least 53% (± 8%) of legal-sized male crabs were soft-shelled. Time periods for other reduction levels are listed in Table 12.

3.4.3 CPUE from FI Sampling Program – CMA E-S

3.4.3.1 Sample Data

The observed CPUE estimates from the FI sampling program in CMA E-S show the peak CPUE of soft-shell legal-sized male crabs occurred in the mid to late winter in 2011 and 2013 and in early spring in 2009, 2010 and 2012 (Figure 20a, blue). However, there were several missed sampling events in 2011 and 2012.

3.4.3.2 Model Results

The CPUE model using FI standardized CPUE data for all years combined, estimated soft-shell legal-sized male crabs reached a peak (0.43 ± 0.28) on March 14 (± 31 days, R^2=0.0.2723, n=70, Table 13; Figure 21a). On any given day between February 8 and April 22 (74 days, Table 13), the relative abundance of soft-shell legal-sized male crabs was equal to, or greater than, 90% of the highest relative abundance of soft-shell legal-sized male crabs over the model year. Time periods for other reduction levels are listed in Table 13.

3.4.4 CPUE from FD Sampling Program – CMA E-S

3.4.4.1 Sample Data

Although there were many missing sampling events in the FD sampling program for CMA E-S, it appears from the available data the peak CPUE of soft-shell legal-sized male crabs occurred in the mid-winter to early spring in all years (Figure 20b, red). There was a possible increase in relative abundance of soft-shell legal-sized male crabs in the late summer of 2011 and fall of 2009, but there are several missing data points close to these times. Note the FI and FD CPUE have different scales (y-axes; Figure 20a, blue).

3.4.4.2 Model Results

The fit of the CPUE model for the FD data was not significant for the "days" term (p(coef. for days>0) = 0.92; Figure 21b).

3.4.5 Comparisons between FI and FD Sampling Programs and Analysis Methods - CMA E-S

3.4.5.1 Sample Data

Sampling was more complete in the FI program (70 sampling events, versus 54 sampling events in the FD program).

Overall, the peak FI and FD proportions (mid-winter to early spring) are similar in timing and magnitude within each individual year (Figure 18). There are variations between the sampling programs at other times of the year (summer-fall), but there are several missing data points, making this difficult to properly compare. Although there were high FI proportions of soft-shell males in the summers of 2010 and 2013, there were no corresponding high CPUE, meaning they represented a small number of individuals.

Soft-shell legal-sized male CPUE calculated from the FD sample data were about 3 times higher than those calculated from the FI sample data (Figure 20).

3.4.5.2 Model Results

This section summarizes the key model results for CMA E-S, presented in previous sections, and compares them between data analysis method (proportion versus CPUE) and sampling programs (FI versus FD) (Table 14).

The date of the peak was similar between the two sampling programs and analysis methods (2nd week of March; Figure 22a, Table 14), varying by only a few days. However, there was much variation in the start dates (December 30 to February 8) and end dates (April 22 to May 19) between the sampling programs and analysis methods (Table 14). Using the proportion analysis method, a 10% reduction from the peak (0.90*Peak) resulted in a FI soft-shell period that was 3 weeks shorter than the FD soft-shell period, whereas using the CPUE analysis method, the FI soft-shell range was shorter still (74 days), but with wide 95% CI around these start and end dates (Figure 22b).

3.5 CRAB MANAGEMENT AREA E-T (TOFINO INDEX AREA)

3.5.1 Proportions from FI Sampling Program – CMA E-T

3.5.1.1 Sample Data

The observed data from the FI sampling program in CMA E-T reveal peak proportions of soft-shell legal-sized male crabs occurred in mid to late winter in all years (Figure 23a, blue). In 2009, there was a second FI peak in the summer equivalent in size to the first (winter) peak. In 2012, proportions quickly increased from a low in October to a peak at the end of December 2012, followed by another peak equivalent in size in February 2013. There was also a high proportion of soft-shell legal-sized males observed in the summer of 2013.

3.5.1.2 Model Results

The proportion model using the FI data for all years combined, estimated a peak proportion (0.48 ± 0.19) of soft-shell legal-sized males on March 21 (± 10 days, R^2=0.3226, n=77, Table 15; Figure 24a). On any given day between January 26 and May 16 (111 days, at 0.90*Peak) at least 43% (± 17%) of legal-sized male crabs were soft-shelled. Time periods for other reduction levels are listed in Table 15.

3.5.2 Proportions from FD Sampling Program – CMA E-T

3.5.2.1 Sample Data

In 2012, the highest FD proportions in CMA E-T were observed on February 1 and May 7, but no sampling events occurred between these dates (Figure 23b, red). Similarly, in 2013, the highest FD proportions were observed on January 15 and April 21, with no other sampling events in-between. We assume that the FD peak proportions of soft-shell legal-sized male crabs likely occurred sometime between these dates for each of 2012 and 2013, just as they did in 2009 to 2011. Secondary peaks in FD proportion of soft-shell legal-sized males also occurred in the summers of 2009, 2010 and in 2013.

3.5.2.2 Model Results

The proportion model using the FD data for all years combined, estimated a peak proportion (0.48 ± 0.11) of soft-shell legal-sized males on March 24 (± 8 days, R^2=0.4134, n=60, Table 16; Figure 24b). On any given day between January 26 and May 23 (118 days, at 0.90*Peak) at least 43% (± 10%) of legal-sized male crabs were soft-shelled. Time periods for other reduction levels are listed in Table 16.

3.5.3 CPUE from FI Sampling Program – CMA E-T

3.5.3.1 Sample Data

The observed CPUE estimates from the FI sampling program in CMA E-T show the peak CPUE of soft-shell legal-sized male crabs occurred in the mid to late winter in most years except 2009,

when there was a summer peak that was slightly higher than the late winter peak (Figure 25a, blue). There was also a small summer peak in 2013.

3.5.3.2 Model Results

The CPUE model using FI standardized CPUE data for all years combined, estimated soft-shell legal-sized male crabs reached a peak (0.48 ± 0.30) on April 15 (± 20 days, R^2=0.0096, n=77, Table 17; Figure 26a). On any given day between March 14 and May 18 (66 days) the relative abundance of soft-shell legal-sized male crabs was equal to, or greater than, 90% of the highest relative abundance of soft-shell legal-sized male crabs over the model year. Time periods for other reduction levels are listed in Table 17. However, note that although the terms "days" and "days^2" were significant, the R^2 value is very low, and caution should be taken if using the results from this model.

3.5.4 CPUE from FD sampling program – CMA E-T

3.5.4.1 Sample Data

As described in the FD proportion section above, there were several missing FD sampling events in the winter and spring of 2012 and 2013 in CMA E-T, which made it difficult to determine with accuracy when the peak CPUE occurred (Figure 25b, red). However, the observed data still revealed CPUE of soft-shell legal-sized male crabs were highest in the mid-winter-early spring for all years; there was also a second peak in the summer of 2009. In general, the CPUE for FD data were much higher than for FI data (Figure 25a, blue; note the different y-axes).

3.5.4.2 Model Results

The CPUE model using FD standardized CPUE data for all years combined, estimated soft-shell legal-sized male crabs reached a peak (0.49 ± 0.36) on March 17 (± 25 days, R^2=0.2981, n=60, Table 18; Figure 26b). On any given day between February 14 and April 21 (67 days, Table 18), the relative abundance of soft-shell legal-sized male crabs was equal to, or greater than, 90% of the highest relative abundance of soft-shell legal-sized male crabs over the model year. However, the data points are quite dispersed and the model's CIs are wide, indicating a high level of uncertainty around the estimates. Time periods for other reduction levels are listed in Table 18.

3.5.5 Comparisons between FI and FD Sampling Programs and Analysis Methods – CMA E-T

3.5.5.1 Sample Data

Sampling was more complete in the FI program (77 sampling events, versus 60 sampling events in the FD program).

In years when there were enough sampling events to determine peak proportions and CPUE, FD peaks appear to have occurred slightly later than FI peaks.

There were high FI proportions of soft-shell males in the summers of 2009 and 2013, with corresponding increases in CPUE at similar times, verifying the proportion observations. This was also true for FD proportions and CPUE in the summer of 2009, but there was no corresponding increase in FD CPUE in the summer of 2013, meaning there were only a small number of crabs represented by the corresponding increased proportion at this time.

Soft-shell legal-sized male CPUE calculated from the FD sample data were almost 4 times higher than those calculated from the FI sample data.

3.5.5.2 Model Results

The peak dates determined from the proportion analysis method were similar for the FI and FD sampling programs (3rd week of March, Table 19, Figure 27a), varying by only a few days. The start and end dates, and peak values were very similar for both sampling programs as well. The peak date determined from the CPUE analysis method was also in the 3rd week of March for the FD sampling program, but the date of the peak from the FI sampling program was a month later (mid-April). This is likely because the FI CPUE in September 2009 was higher than the FI CPUE in the spring of 2009. Since the CPUE data were standardized by model year, all of the 2009 CPUE were standardized to the September CPUE, and this appears to have skewed the model to the right, resulting in a later peak date for this data set. Until more data are collected, caution should be taken if using the results from the CPUE model using FI data.

Note both the FI and FD peak dates resulting from the CPUE analysis had wide 95% CI (± 20 to 25 days; Table 19). At the 10% reduction from the peak (0.90*Peak), the soft-shell period was similar for both sampling programs with the proportion analysis method (about 114 days). However, using the CPUE analysis method, the soft-shell period was shorter (67 days) and started later (mid-February to mid-March, Table 19) for both sampling programs, but with wide 95% CI around their start and end dates (Figure 27b).

3.6 CRAB MANAGEMENT AREA G

In 2013, new service providers were hired to conduct the FI and FD sampling in CMA G. There appeared to be lots of variability in the catches in this year, which may be due to the service providers not being familiar with the area.

3.6.1 Proportions from FI Sampling Program – CMA G

3.6.1.1 Sample Data

Although the observed data from the FI sampling program in CMA G (Village Channel (2009 to 2013) and Retreat Passage (2010 to 2013) Index Areas) show peak proportions of legal-sized male crabs occurred in the spring for all years, there were many missing sample dates, especially in the winter months, so the peak may have occurred prior to this (Figure 28a). There was no sampling event performed in July 2009, when there may have been a secondary peak, as observed in other CMAs, but there was an increase in the fall in 2009 (from Village Channel data only). There was also high variability during the summer and fall of 2013.

3.6.1.2 Model Results

The proportion model using the FI data for all years combined, estimated a peak proportion (0.69 ± 0.20) of soft-shell legal-sized males on March 24 (± 5 days, R^2=0.6274, n=97, Table 20; Figure 29a). On any given day between February 5 and May 12 (97 days, at a reduced level of 0.90*Peak) at least 62% (± 18%) of legal-sized male crabs were soft-shelled. Time periods for other reduction levels are listed in Table 20.

3.6.2 Proportions from FD Sampling Program – CMA G

3.6.2.1 Sample Data

There were insufficient data from the FD sampling program in CMA G (Village Channel (2009 to 2013) and Retreat Passage (2010 to 2013) Index Areas combined) to estimate seasonal trends (Figure 28b).

3.6.2.2 Model Results

Despite low sampling event numbers for any one year and index area, when combined, a significant model fit was achieved. The CPUE model using the FD data for all years combined, estimated a peak proportion (0.63 ± 0.18) of soft-shelled legal-sized males on March 21 (± 6 days, R^2=0.8678, n=23; Table 21; Figure 29b). On any given day between February 7 and May 4 (87 days, at 0.90*Peak) at least 57% (± 16%) of legal-sized male crabs were soft-shelled. Time periods for other reduction levels are listed in Table 21.

3.6.3 CPUE from FI Sampling Program – CMA G

3.6.3.1 Sample Data

The observed CPUE estimates from the FI sampling program in CMA G illustrate the peak CPUE of soft-shell legal-sized male crabs occurred in the spring for all years although there were several missed sampling events in the winter when a peak may have occurred (Figure 30a). There was no sampling event performed in July 2009, when there may have been a secondary peak, as observed in other CMAs. There was a small increase in CPUE in the late summer of 2013.

3.6.3.2 Model Results

The CPUE model using FI standardized CPUE data for all years combined, estimated that soft-shell legal-sized male crabs reached a peak (0.45 ± 0.39) on March 24 (± 18 days, R^2=0.1852, n=97, Table 22; Figure 31a). On any given day between February 21 and April 26 (65 days, at 0.90*Peak, Table 22), the relative abundance of soft-shell legal-sized male crabs was equal to, or greater than, 90% of the highest relative abundance of soft-shell legal-sized male crabs over the model year. However, the data are quite scattered and the R^2 is low (0.1852), so caution should be used when interpreting these results. Time periods for other reduction levels are listed in Table 22.

3.6.4 CPUE from FD Sampling Program – CMA G

3.6.4.1 Sample Data

There were insufficient data from the FD sampling program in CMA G to estimate seasonal trends (Figure 30b).

3.6.4.2 Model Results

Despite low sampling event numbers for any one year and index area, when combined, a significant model fit was achieved. The CPUE model using the FD data for all years combined estimated a peak relative abundance (0.84 ± 0.22) of soft-shell legal-sized male crabs on March 22 (± 22 days, R^2=0.6557, n=23, Table 23; Figure 31b). On any given day between February 9 and May 3 (84 days, at 0.90*Peak, Table 23), the relative abundance of soft-shell legal-sized male crabs was equal to, or greater than, 90% of the highest relative abundance of soft-shell legal-sized male crabs over the model year. Time periods for other reduction levels are listed in Table 23.

3.6.5 Comparisons between FI and FD Sampling Programs and Analysis Methods - CMA G

3.6.5.1 Sample Data

Sampling was more complete in the FI program (97 sampling events, versus 23 sampling events in the FD program).

The very limited soft-shell legal-sized male CPUE values calculated from the FD sample data were approximately two times higher than those calculated from the FI sample data.

3.6.5.2 Model Results

There was a high degree of consistency in the model results for both sampling programs (Table 24). The date of the peak was similar (3rd week of March) for both analysis methods using both types of sampling data (Figure 32a). In addition, the soft-shell period defined by the 10% reduction from the peak (0.90*Peak) began in early February and ended in early May (84 to 97 days) for three of the four combinations of analysis methods and sampling data (Figure 32b). The CPUE method using the FI data had a shorter soft-shell period (65 days) which started in late February and ended in late April.

The FI peak relative abundance was much lower (0.45) than the FD peak relative abundance (0.84; Table 24).

3.6.6 Comparisons Between Index Areas Within CMA G

Results from the two analysis methods using data from the two sampling programs at the 'index area' level (Village Channel and Retreat Passage) within CMA G are presented in Appendix B (Tables B1 to B2; Figures B1 to B4). Note the low sample sizes for individual index areas for some years increases the uncertainty of these results, as compared to the combined data for the CMA. There were so few FD sampling events performed in either of the two index areas that the models were not run for this sampling program. Only model results using FI data are presented.

Although there were some large data gaps, when there were data, the observed FI proportions were similar in timing and magnitude between the two index areas within individual years 2010 to 2012 (Figure B1, blue lines). The sampling programs did not begin in Retreat Passage until 2010, so there were no 2009 results for this index area. There was a great deal of variability in 2013, both between index areas, and between sampling events within individual index areas.

The proportion model using FI data produced similar peak proportions (0.68 and 0.69) for the two index areas with peak dates 10 days apart from each other (March 21 at Village Channel and March 31 at Retreat Passage; Figure B2; Table B1). It also produced a soft-shell period at the 0.90*Peak level for Retreat Passage Index Area that started 17 days later than for Village Channel Index Area, although the end dates for both index areas were similar (only 5 days apart). Part of these differences may be due to the lack of 2009 data for Retreat Passage.

As with the proportion data, the observed FI CPUE data (Figure B3, blue lines and markers) had large gaps for both index areas, especially for the early part of the year when legal-sized male crabs are expected to be soft. The FI CPUE data were not as similar between index areas as the observed FI proportions. Consequently, results for the CPUE model (Figure B4; Table B2) were more variable between the two index areas than the results for the proportion model. In particular, the peak relative abundance of 0.64 occurred March 15 for Village Channel, whereas the peak relative abundance for Retreat Passage was much lower (0.38) and occurred 3 weeks later on April 7 (Table B2). The soft-shell periods from the FI CPUE analyses at the 0.90*Peak level were shorter for both index areas (59 to 73 days; Table B2) than those defined from the FI proportion analyses (88 to 99 days; Table B1), but had higher variability around the start and end dates.

The data for Retreat Passage was lacking 2009 data, had a low sample size (n=40), was missing crucial early year sampling events for several years, did not fit the CPUE model very well (R^2 = 0.1223), and had the widest variability around the means (Table B2). CPUE model results should not be used at the index area level for Retreat Passage.

3.7 INTERANNUAL VARIATION

The above sections have discussed results for each CMA, for all years combined. In this section we describe results for individual years, 2009 to 2013, by CMA. As noted in previous sections, locations and years with smaller sample sizes (due to missed sampling events, especially in the FD sampling program) decreased the models' abilities to fit observed data. We therefore restricted analyses for individual years for each CMA, by only using data from the FI sampling program and applying the proportion analysis method.

3.7.1 CMA H

The results for the year 2009 were unusual in CMA H, as it was the only year that had two large peaks, one in the spring and one in the summer. No other year in CMA H had a large summer peak. The peak dates for soft-shell male crabs in CMA H varied among individual years (2009 to 2013) by as much as 49 days (Figure 33, Table 25). However, the years 2009 to 2012 had individual peak dates ranging from March 10 to 27, a maximum difference of only 17 days, whereas in 2013, the peak occurred as early as February 6. This early peak appears to be influenced by an increase in soft-shell proportions starting in October 2012, which is earlier than usual. Note that the model results for all years combined produced a peak date of March 15 (Table 10).

The CMA H start dates for the soft-shell periods, if defined by the 0.90*Peak level, differed among years in the same direction as the peak dates (i.e. the start dates occurred earlier when the peak was earlier; Table 25). There was a large range in the start dates of the winter-spring soft-shell period (81 days at the 0.90*Peak level), from December 7 (in 2012, but part of the 2013 model year) to February 26 (in 2009; Table 25). In contrast, the difference between end dates of the spring soft-shell period varied by 42 days, from April 10 (in 2013) to May 22 (in 2010). The length of the soft-shell period (as determined by the 0.90*Peak level) ranged among years from 60 to 124 days (Table 25), compared to 105 days for all years combined (Table 10). Model results for CMA H peak dates and soft-shell periods for all years combined appear to be reasonable estimates from those values obtained from each year individually.

3.7.2 CMA E-S

The model results were not significant for three of the five individual years (2010, 2011, and 2013), probably due to small sample sizes, as this CMA represents only one index area (Sooke; Figure 34, Table 26). Missed sampling events at crucial times of the year may also have caused the model to produce results that were not significant or that did not make biological sense. The peak date in 2009 was April 15, whereas the peak date was earlier in 2012 at March 23. In comparison, the peak date for all years combined for this CMA was March 12 (Table 14).

The CMA E-S soft-shell periods (of the two years with significant results), if defined by the 0.90*Peak level, varied from February 4-May 15 in 2012 to February 28-June 4 in 2009, both approximately 98 days long.

3.7.3 CMA E-T

The model results were not significant for two of the five years (2009 and 2013), probably due to small sample sizes, as this CMA represents only one index area (Tofino; Figure 35, Table 27). The peak dates for 2010 to 2012 ranged from March 4 (in 2010) to April 2 (in 2011), whereas the peak date for all years combined for this CMA was March 21 (Table 19).

The CMA E-T soft-shell start dates (of the three years with significant results), if defined by the 0.90*Peak level, varied from January 15 (in 2010) to March 9 (in 2011), a difference of 53 days (Table 27). In contrast, the end dates of the soft-shell period only varied by 6 days, from April 24 (in 2010) to April 30 (in 2012).

3.7.4 CMA G

There were many missed sampling events for this CMA. The model results were not significant for 2013, probably because there were no sampling events in this CMA between October 1 and February 7 (Figure 36, Table 28). The peak dates for 2009 to 2012 ranged from March 8 (in 2010) to April 11 (in 2009), whereas the peak date for all years combined for this CMA was March 24 (Table 20).

The CMA G soft-shell start dates (of the four years with significant results), if defined by the 0.90*Peak level, varied from January 13 (in 2010) to February 16 (in 2009), a difference of 35 days (Table 28). In contrast, the end dates of the soft-shell period varied by almost 2 months, from April 12 (in 2011) to June 8 (in 2009).

3.7.5 Comparisons Among Years

When examining the model output for the five model years within a CMA, there are obvious variations in the shapes of the plots among the years. The differences include: the height of the peaks (i.e. low or high peak values); early or late peak, start and end dates; and the length of the soft shell periods. By comparing the annual results over all four CMAs, certain characteristics stand out for individual model years. These are outlined below for model years and CMAs with significant model results only (proportion model using FI data, for the late winter-early spring soft-shell peaks; Tables 25 to 28, Figures 33 to 36). In other words, this excludes the non-significant results for 2009 in CMA E-T, 2010 and 2011 in CMA E-S, and 2013 in CMAs E-S, E-T and G. Soft-shell periods are all compared at the 0.90*Peak level. This level of reduction from the peak is only used here as an example for the comparisons.

2009 – This model year had the latest peak dates (March 27 – April 15), latest start dates (February 16 – 28), and latest end dates in CMAs E-S and G (June 4 - 8), but not in CMA H. This is the only model year that the model recognized a large secondary peak in the summer as seen in CMA H (although there was a summer peak in the observed data for CMA E-T in the summer of 2009).

2010 – This model year had the earliest peak dates (March 4 – 8) in CMAs E-T and G, and the earliest start dates (January 13-28), except for 2013 in CMA H. The end dates were variable. Model year 2010 had some of the longest soft-shell periods (99 to 114 days), and along with 2011, had the lowest peak proportion values (i.e. model height) (0.39 – 0.58). 2010 may possibly be considered the model year with the least synchronous male soft-shell period, due to its very long soft-shell periods, as compared to the other model years. However, the model results with the longest soft-shell period occurred in 2013, so it may have been the least synchronous model year, but it only had significant model results for CMA H, so it cannot be verified for all CMAs.

2011 – This model year had similar peak proportion dates in CMA H and G (March 10-13), variable start dates, and early end dates (April 12 – 28). Model year 2011 had the shortest soft-shell periods (50 to 78 days) at this level of reduction from the peak, and may be considered as having the most synchronous male soft-shell period of all the model years. Along with 2010, this model year had the lowest peak proportion values (0.39 – 0.58).

2012 – This model year had "average" peak (March 16 – 23) and start dates (February 4 – 11) that were similar among all four CMAs. It also had similar end dates for three of the CMAs (April 28 – 30). This model year had soft-shell periods of average length, and the highest peak proportion values (0.76 – 0.98). However, this model year also had the lowest number of sampling events.

2013 – There were only significant model results for this model year in CMA H, so there are no other CMA results to verify the outcome. However, in CMA H, model year 2013 had the earliest peak (February 6), the earliest start date (December 7, 2012), and the earliest end date (April 10) of all the model years and CMAs. This model year also had the longest soft-shell period (124 days).

4 DISCUSSION

Dungeness crab biological data were collected for five years (2009 to 2013) in the south coast of BC from seven index areas in CMAs E-S, E-T, G, and H. Two data collection programs were conducted by third-party service providers to obtain FD and standardized FI crab catch data. Two analytical methods were applied to the sample data: a proportion model to estimate what proportion of the legal-sized male (sampled) population was soft-shelled; and, a CPUE model (using CPUE data standardized within each year) to estimate the relative abundance of soft-shell legal-sized male crabs collected in traps irrespective of the sampled legal-sized male population size. These two methods answered different questions. The proportion method provided information about the abundance of soft-shell legal-sized male crabs relative to the abundance of hard legal-sized male crabs at a given time, and highlights when most legal-sized male crabs were soft. However, proportions do not provide any information about the number of crabs caught; it was possible only a few crabs were captured at a particular time interval, but a high proportion may have been soft. As population sizes may have changed from year to year, CPUE estimates were standardized to provide the relative abundance of soft-shell legal-sized males for each model year. These standardized estimates highlight when trap gear caught many soft-shell crabs, but they do not indicate whether this was a small or large proportion of the total legal-sized male population. We provide insights into peak timing, length of time, and variability around these dates when legal-sized male Dungeness Crabs were estimated to be in soft-shell condition.

Although we found that some amount of soft-shell legal-sized male Dungeness Crabs could be present at almost any time of the year, most soft-shell male crabs were observed from the late winter to spring months, and in some years, were also observed in high numbers in the summer. The peak proportion estimates of soft-shell crabs (from CMAs E-S, E-T, G and H, using 2009 to 2013 data from both sampling programs) ranged from 48 to 69% and occurred in March (5 - 24). The CPUE model produced peak relative abundance estimates ranging from 43 to 84% that also occurred in March (14 - 27), except in CMA E-T where it occurred April 15 using FI data (although this model result had a very low R^2 value of 0.0096 and should be used with caution). In addition to the peak date, we reported 5%, 10%, 15%, 25% and 50% reductions from the peak value in order to highlight time periods when a certain proportion or relative abundance of crabs were soft-shelled. For example, proportion data from the FI sampling program produced a soft-shell period (based on a 10% reduction from the peak, or 0.90*Peak) starting between January 15 and February 5 and ending between May 7 and May16 for all locations when, on any given day, at least 43% (CMA E-T) to 62% (CMA G) of all legal-sized males were in soft-shell condition. Soft-shell periods at this reduction from the peak averaged 107 days (3.5 months). Changes between different reduction levels often did not produce large differences in threshold proportion or S-CPUE values of crabs but did change the length of the soft-shell periods considerably. This was due to the modelled curves being fairly

flat throughout the winter/spring period. Regardless, the modelled soft-shell periods correspond well with other research conducted in BC and in the US inside waters of Washington State (Puget Sound) that determined the male molt generally occurs between February and July, prior to the female summer molt and mating period (Butler 1961; soft-shell sampling program in CMA A; soft-shell closures in CMAs I and J; WDFW 2015c). However, timing of the adult male molt varies on the west coast of North America. In California, Oregon, and Washington, the molt occurs between June and November, and follows moulting and mating of adult females in the spring (mid-February to mid-May; Hankin *et al.* 1997). The male molt starts earlier in California (June to August; Orcutt 1977; Hankin *et al.* 1997) and occurs progressively later as one moves northward (August in Oregon and September in Washington; Hankin *et al.* 1997; ODFW 2015; WDFW 2015d).

Both the FI and FD sampling programs produced similar trends in peak timing of soft-shell legal-sized males, which was encouraging and points to the merit of both types of sampling programs for detecting soft-shell periods. In CMA H and CMA E-S, model results showed peak timing occurred from 3 to 10 days later and soft-shell periods were shorter when using data collected by the FI program than by data from the FD program. These results may be due to different timing or frequency of the sampling events in each of the sampling programs, and is discussed further in Sections 4.1.2 (Data Collection Times) and 4.1.3 (Missed Sampling Events). Results were similar between FI and FD sampling programs for CMA E-T and CMA G, with the exception of the model CPUE using FI data for CMA E-T, where the peak date is one month later than the FD CPUE peak, and the proportion peaks for both sampling programs (this particular model result had a very low R^2 value of 0.0096, and should be used with caution).

FI sampling was standardized in terms of trap type, bait type, and soak time, whereas FD sampling was not standardized and therefore had more variability with regard to the kinds of fishing gear used. In some years and locations there was infrequent and inconsistent data collection that occurred in both sampling programs, but more often in the FD sampling program. Fewer sampling events from commercial vessels and missed sampling events at critical times of the year sometimes produced model results that were not statistically significant or biologically reasonable. This inconsistency of data collection between the two sampling programs made it difficult to compare the two programs' model results.

Proportion analyses produced longer soft-shell periods than CPUE analyses. Results regarding peak intervals and start/end dates were also generally less variable and more precise with the proportion analyses. The proportion method therefore may be considered more conservative than the CPUE (relative abundance) method.

CPUE data revealed soft-shell legal-sized male crabs were caught in considerably higher numbers in commercial traps compared to standardized gear, sometimes as much as two to four times higher. Even with trap haul restrictions already in place, commercial gear captured soft-shell crabs in sufficient numbers from which we could detect soft-shell periods. This is not surprising as their soak times were longer, and commercial fishers are experts at catching crabs.

Proportion model results using FI data showed that at a 10% reduction level from the peak (0.90*Peak), legal-sized male crabs in CMA E-S, the southernmost CMA, had the earliest soft-shell peak and start dates, but lacked the 2009 summer molt observed in CMA H. These parameters were most similar to those for CMA H, varying by only a few days. Legal-sized male crabs in CMA E-T had soft-shell peak, start and end dates that were 3 to 9 days later than CMA H crabs, and also had a summer peak in 2009, similar to CMA H, suggesting there is recruitment from mixed sources. The most northern location, CMA G, had the latest soft-shell peak and start dates, but they varied by only a few days with CMA E-T. This shows there may

be a latitudinal connection with male crab soft-shell timing, with soft-shell peaks occurring later the further north, but by an overall difference of only about 12 days. There is other evidence in the literature of latitudinal differences in timing of molt timing for the Dungeness Crab, as described previously in this section, with molting occurring progressively later from California to Washington.

4.1 UNCERTAINTIES

4.1.1 Defining Soft-shell Crabs

In this paper, soft-shell crabs are defined as those crabs with shells that were soft to any degree (i.e. could flex with finger pressure) and from a biological perspective, the notches shell condition codes 5, 4, 3 and 2. Crabs are in shell condition 2 for approximately 2 months, and at some point become sufficiently hard enough to be legally retained by industry. From a market perspective, these crabs are not considered soft. Unfortunately, there is no information in the collected data to differentiate between these 2 stages of shell condition 2. In addition, the assignment of shell hardness codes is somewhat subjective, creating additional uncertainty. For these reasons, we included all soft-shell crabs, including those with shell condition 2, in our definition of soft-shell. As a result, the model output may have produced slightly later and later for estimated soft-shell periods presented in the tables than those that may have resulted if marketable crabs could have been excluded from shell code 2.

4.1.2 Missed Sampling Events

Many sampling events were missed in both sampling programs, especially in 2011 and 2012, but, overall, sampling requirements were met more consistently in the FI sampling program. Missed sampling events during late fall and winter months were more of an issue in the FID sampling program and may have been related to inclement weather conditions and shorter daylight hours that would have made it more challenging for service providers to get out on the water, and fewer commercial vessels were likely fishing during these times, especially if they were starting to encounter higher catches of soft-shell crab.

Missed sampling events, especially at particular times of the year, decreased the model's ability to precisely fit observed data. Consequently, model outputs for individual years were less reliable compared to model outputs for combined years and/or index areas. When there were only a few sampling events (as occurred in certain individual years), one or two outliers had a large impact on model results. However, at the CMA level of analysis, where data from two or three index areas were combined to produce a larger sample size, missed sampling events had less effect on model outcomes.

There were occasions when the majority of sampling events from the beginning of the model year (i.e. October through January) were missed, especially in the FID sampling program. In these scenarios, the model was constructed using sampling events between February and September, and the section of the plot before February was extrapolated, which often produced large uncertainties around the outcome. If data had been collected before February and these sampling events had shown low values as expected, then the section of the plot before February would have been associated with lower values, and soft-shell period start dates would have occurred later. For example, in the Nanaimo Index Area (Figure xxx), FID sampling was missed in October to mid-January for all years except 2010. As a result, the CPUE model using FID data produced a start date (January 16) that was three weeks earlier than the FI CPUE model (February 6). Moreover, the fit of the CPUE model using FID data was not significant for the "days" term (p-coef. for days=0) = 0.92).

Missed sampling events particularly affect the CPUE data, as these values are standardized for each individual model year based on the highest CPUE for that year, with all other CPUE standardized relative to that highest value. If a sampling event is missed during the peak of the soft-shell period, then all other CPUE will be standardized to the next lower CPUE. This may affect the model results if it is not close to the peak time period, especially if that CPUE is much lower than what would have been the highest CPUE.

In general, consistent crab biological data collection, as outlined in the survey methods described in the Crab By Trap IFMP, is of utmost importance so that there are minimal data gaps, which will help modeling efforts produce significant and biologically reasonable results. Fisheries data such as those data collected for this research inherently contain a considerable amount of random error. The smaller the data sets, the more negative impact outliers will have on model outputs.

4.1.3 Soak Time Methodology Differences

The FI and FD sampling programs employed different trap soak time methods. The FI program aimed for a standardized soak time of 24 hours; soak times between 18 and 28 hours were acceptable for use in data analyses, whereas any traps with soak times <18 hours or >28 hours were excluded. The FD program had trap soak times that ranged from 23 hours to a maximum of 432 hours (or 18 days, the maximum allowed soak time in the Crab By Trap commercial fishery). There are many reasons for longer soak times in the commercial fishery. First, there are trap haul restriction times that apply in some DMAs at certain times of the year (during approximate soft-shell periods) to reduce the potential injury to soft-shell crabs due to increased water pressure on soft crabs from hauling traps quickly through the water and from frequent handling of crabs (Kruse et al. 1998). Restricting trap haul frequency to once a week means the traps are soaking for approximately 168 hours at a time for approximately three months. Secondly, if there is inclement weather, traps may have to stay in the water longer than anticipated to avoid unsafe boating conditions. And thirdly, fishers believe leaving traps down longer will allow most sublegal crabs to escape, leaving a "cleaner" catch of legal-sized crab.

It is unknown what affect longer soak times in the FD sampling program may have on the catch. Longer soak times may provide more opportunity for cannibalism to occur, especially on vulnerable soft-shell crabs. Overall FD catch is higher than FI catch, but that is most likely due to longer available time for crabs to enter the traps. However, there is not a linear relationship between increased time and increased catch, as the bait becomes increasingly ineffective over time, and will therefore attract crabs at a lower rate. Although the catch rates for FD traps may be higher than FI traps, standardizing CPUE within each year for each program allows comparison of peak timing of the relative abundance between years and between sampling programs.

4.1.4 Model Uncertainties

The primary objective for the modeling is to determine if and how proportions and relative abundance of soft-shell legal-sized crabs may change with calendar "days". We therefore incorporated both linear and quadratic effects of days on the proportion and relative abundance in the models. To examine the importance of these effects, we monitored their posterior distributions to determine if zero is far away from the centers of the distributions. Specifically, when an estimated 95% credible interval does not cover zero, then the corresponding effect is regarded to be significant. Existence of significance for both the linear and quadratic effects provides a statistical justification for the validity of model outputs, such as the day for the peak proportion or relative abundance. Effects of days on the proportion and relative abundance of soft-shell legal-sized crabs were found to be significant in most cases in the current study.

However, precaution should be used when there are low numbers of data points and the model outcome is clearly against biological understanding (or wisdom). For instance, using the FI data collected from CMA G in 2013, the model produced a graph showing that the proportion of soft-shell legal-sized crabs decreased from January or February to late June, and then increased thereafter in that year. This pattern of change in the proportion contradicts the biological understanding that the proportion is expected to peak sometime in the spring. This model output should probably be disregarded based on the biological evaluation, even though both the linear and quadratic effects of days on the proportion are statistically significant. In addition, we calculated 95% credible intervals for quantities derived in the modelling process, such as the start or end date for a soft-shell period associated with 90% reduction from the peak proportion. Thanks to the nature of Bayesian modelling, posterior probabilities for derived quantities could be easily produced (Kéry 2010). These estimated credible intervals provide the fishery managers with quantitative information about uncertainties when a management scheme is to be designed.

We also calculated R^2 to examine the goodness of model fit to the data. Since the same data set was not used by two or more different models, there is little meaning in comparing R^2s among different model fits in the current study. R^2 may only be used to indicate closeness between the best-fitted model curve and the data points in the current study. The model's output reliabilities are primarily assessed based on whether the linear and quadratic effects are significant or not.

4.1.5 Interannual Variability

The year 2009 was the most unusual compared to the other four years during the study because the spring soft-shell period occurred later, and there was a substantial secondary soft-shell period during the summer in some locations, but not all. This 2009 summer soft-shell period (June to September) was observed in all index areas in CMA H, and in CMA E-T, but not in CMA E-S. Sampling did not begin in Retreat Passage Index Area until 2010, and the July 2009 sampling event was missed in Village Channel, so we do not have evidence whether it occurred or not in CMA G.

Some differences in peak, start and end dates between years (and between index areas) may be due to the fact that sampling was not undertaken on the same calendar days each year, or in each index area, as noted earlier (section 4.1.2). However, each individual year seemed to have some unique characteristics (i.e. low or high peak values; early or late peak, start and/or end dates; or, short or long soft-shell periods) that were repeatedly observed over several CMAs, meaning varying sampling dates were not necessarily the reason for these interannual differences. It is more likely that variations in environmental conditions each year, such as temperature, ocean currents, or food availability influenced these differences. There is much evidence in the literature that water temperature affects various stages of growth in the life history of Dungeness crabs. Reilly (1983) observed earlier peak hatching periods in years with warmer sea surface temperatures. Kondzela and Shirley (1993) found the intermoult period (time between moults) for juvenile crabs was longer for crabs held in colder water, with the shortest intermoult period around 15 to 18 C°. Sulkin *et al.* (1996) found similar results in megalopae and juvenile Dungeness development, where intermoult periods were shortest for crabs held in warmer water. Although Terwilliger and Dumler (2001) also found growth of juvenile Dungeness crab increased with increased temperature, they observed that increased food availability affected growth rates in juvenile Dungeness crab more than increased temperatures (i.e. juvenile crabs fed high food levels grew larger and faster than those fed low food levels). Similarly, a recent study by McLean and Todgham (2015) also found that although food limitation reduced moulting frequency and growth increments in juvenile Dungeness crabs,

crabs could maintain stress tolerance to high temperatures under food limitation, and surmised reduced growth was a physiological trade-off for survival under physical stress. The effect of temperature variation on Dungeness Crab moult timing and length of soft-shell periods in BC requires further research.

5 CONCLUSIONS

1. Results derived from standardized fishery-independent sampling program proportion data best describe when legal-sized male Dungeness crabs are in soft-shell condition. Results derived from the commercial vessel sampling program CPUE data best describe when the commercial fleet catches high numbers of soft-shell crabs.
2. Based on modelled results and a 10% reduction from the peak (0.90 × Peak) using proportion data from the fishery-independent sampling program, the proportion, soft-shell period, and peak time for each CMA are:

   CMA H: 48% between January 23 – May 7 (± 10 days), with a peak on March 15;

   CMA E-S: 58% between January 15 – May 10 (± 12 days), with a peak on March 12;

   CMA E-T: 43% between January 26 – May 16 (± 14 days), with a peak on March 21;

   CMA G: 62% between February 5 – May 12 (± 16 days), with a peak on March 24.
3. Depending on management objectives, reduction levels from the peak other than the 95%, 90%, 85%, 75% and 50% levels presented in this paper can be used to determine periods of time when a certain proportion or relative abundance of legal-sized male crabs are soft.
4. Biological sampling programs designed to determine crab soft-shell periods with high certainty require consistent and frequent sampling of sufficient numbers of crabs throughout the year to produce meaningful results. This is an important requirement of future fishery-independent or commercial vessel sampling programs. In addition, more years of data need to be collected to determine the extent of yearly variation. Until then, caution should be used if using these models for management purposes.
5. Further research is needed to understand environmental determinants of the observed inter-annual variability in legal-sized male soft-shell periods in southern BC.

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8 TABLES

Table 1. Commercial fishery management measures that may help protect soft-shell crabs in Crab Management Areas (CMAs) E, G, and H (DFO 2014).

CMA	Geographic Location	Subarea Licensing	No. Licenses	No. Traps	Non-Retention Soft-shell	Seasonal Closure	Trap Haul Restrictions[1]	Hanging Bait Prohibited?
E	WCVI		36	350	Yes	No	Mar 15 – May 15 (1) May 16 – Dec 31 (2) in Area 20-3 to 20-5	No
		Sooke (E-S)	10	42	Yes	No	Jan 1 - Mar 31 (1) Apr 1 - Dec 31 (2)	No
		Tofino (E-T)	24	67	Yes	No	Jan 1 - Mar 31 (1)	Yes
		Quatsino (E-Q)	2	200	Yes	No	Mar 15 – May 15 (1)	No
G	Johnstone Strait		19	295	Yes	No	Jan 15 - Apr 15 (1)	No
H	Strait of Georgia		51	253	Yes	No	Jan 15 - Apr 15 (1)	Yes

[1] (1) Haul once per week

(2) Haul twice per week

Table 2. Definitions of crab management areas (CMAs) and index areas used in the soft-shell crab biological sampling program, 2009 to 2013. Crab biological sampling only occurred in designated index areas in each CMA. (PFMA = DFO's Pacific Fisheries Management Area; Subarea = division of a PFMA).

CMA	Index Area	PFMA	Subarea
H	Nanaimo	17	13, 14, 15, 16
	Ganges	18	3
	Sidney	19	5, 6
E-S	(Sooke)	20	4, 5, 6, 7
E-T	(Tofino)	24	6, 8, 9
G	Village Channel Indian Channel Beware Passage	12	6, 26
	Retreat Passage	12	39
	Malcolm Island (2009 only)	12	4, 8, 17, 18

Table 3. Dungeness Crab shell condition, approximate time since the last moult, and corresponding shell condition codes.

Shell Plasticity	Shell Condition	Time Since Last Moult	Shell Code
Soft	Moulting – crack at suture line	0 days	5
	Plastic soft	few days	4
	Crackly soft	1 week – 1 month	3
	Springy soft	1 – 3 months	2
Hard	New hard	3 – 6 months	1
	Between new and old hard	6 – 12 months	8
	Old hard	12– 24 months	6
	Very old hard	>24 months	7

Table 4. Number of samples recorded for 2009 to 2013 combined, for all index areas and crab management areas (CMAs), not including samples recorded from traps with long soaks (fishery-independent (FI) sampling program only) or bad trap usability codes. (LM = legal-sized male crab; FD = fishery-dependent sampling program).

CMA	Index Area	Sampling Type	Soft LM	All LM	All Crabs	# Traps Sampled	# Sample Days
H	Nanaimo	FI	1,191	3,371	16,782	1,818	85
		FD	1,519	4,530	10,171	989	54
	Ganges	FI	1,333	3,169	16,227	2,146	84
		FD	1,740	4,931	10,640	1,376	54
	Sidney	FI	1,195	3,401	14,796	2,248	82
		FD	1,710	4,295	11,738	1,666	65
	Total	FI	3,719	9,941	47,805	6,212	251
		FD	4,969	13,756	32,549	4,031	173
		FI + FD	**8,688**	**23,697**	**80,354**	**10,243**	**424**
E-S	(Sooke)	FI	1276	2,565	14,795	1,507	73
		FD	2,827	6,081	11,431	1,104	57
	Total	**FI + FD**	**4,103**	**8,646**	**26,226**	**2,611**	**130**
E-T	(Tofino)	FI	1,051	3,086	15700	2,437	80
		FD	1,976	5,092	12,066	1,679	63
	Total	**FI + FD**	**3,027**	**8,178**	**27,766**	**4,116**	**143**
G	Village	FI	1,042	2,438	10,793	1,343	59
	Channel	FD	727	1,576	3,707	386	18
	Retreat	FI	444	1,188	6,803	930	41
	Passage	FD	193	446	993	113	5
	Total	FI	1,486	3,626	17,596	2,273	100
	CMA G	FD	920	2,022	4,700	499	23
		FI + FD	**2,406**	**5,648**	**22,296**	**2,772**	**123**
OVERALL		FI	**7,532**	**19,218**	**95,896**	**12,429**	**504**
		FD	**10,692**	**26,951**	**60,746**	**7,313**	**316**
		FI + FD	**18,224**	**46,169**	**156,642**	**19,742**	**820**

Table 5. Number of fishery-independent (FI) and fishery-dependent (FD) sampling events completed each calendar year (of a target of 18 events per year), and the % frequency of the target (in brackets), for each crab management area (CMA) and index area.

CMA	Index Area	Year	FI	FD
H	Nanaimo	2009	18 (100%)	16 (89%)
		2010	17 (4%)	13 (72%)
		2011	16 (89%)	7 (39%)
		2012	16 (89%)	3 (17%)
		2013	18 (100%)	15 (83%)
	Ganges	2009	18 (100%)	11 (61%)
		2010	17 (94%)	15 (83%)
		2011	16 (89%)	10 (56%)
		2012	16 (89%)	5 (28%)
		2013	18 (100%)	13 (72%)
	Sidney	2009	18 (100%)	14 (78%)
		2010	16 (89%)	16 (89%)
		2011	15 (83%)	10 (56%)
		2012	15 (83%)	8 (44%)
		2013	18 (100%)	17 (94%)
E-S	Sooke	2009	18 (100%)	15 (83%)
		2010	16 (89%)	15 (83%)
		2011	12 (67%)	8 (44%)
		2012	11 (61%)	7 (39%)
		2013	16 (89%)	12 (67%)

CMA	Index Area	Year	FI	FD
E-T	Tofino	2009	18 (100%)	16 (89%)
		2010	17 (94%)	15 (83%)
		2011	15 (83%)	12 (67%)
		2012	14 (78%)	8 (44%)
		2013	18 (100%)	12 (67%)
G	Village Channel	2009	13 (72%)	10 (56%)
		2010	13 (72%)	3 (17%)
		2011	14 (78%)	3 (17%)
		2012	9 (50%)	1 (6%)
		2013	10 (56%)	2 (11%)
	Retreat Passage	2009	-	-
		2010	12 (67%)	2 (11%)
		2011	13 (72%)	1 (6%)
		2012	8 (44%)	2 (11%)
		2013	8 (44%)	0 (0%)
	Malcolm Island	2009	12 (67%)	5 (28%)
		2010	-	-
		2011	-	-
		2012	-	-
		2013	-	-

*Table 6. Crab Management Area H 2009 to 2013 results of the proportion model using fishery-independent (FI) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 14a). The predictable variables "days" and "days^2" were significant. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the proportion values; Start Date and End Date = estimated start and end dates of the time period when proportions were at, or above, the particular reduction level from the peak proportion; Start to End Length = number of days from the estimated start to end dates; Peak / or Start and End Date Variability = 95% CI around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	Prop of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
H	**Peak**	0.38	**0.54**	0.70		**Mar 15**		**1**	**5**	0.4082	242
	0.95*Peak	0.36	**0.51**	0.67	**Feb 07**		**Apr 22**	75	**8**		
	0.90*Peak	0.34	**0.48**	0.63	**Jan 23**		**May 07**	105	**10**		
	0.85*Peak	0.32	**0.46**	0.60	**Jan 12**		**May 18**	127	**11**		
	0.75*Peak	0.28	**0.40**	0.53	**Dec 24**		**Jun 08**	165	**13**		
	0.50*Peak	0.19	**0.27**	0.35	**Nov 17**		**Jul 13**	239	**14**		

*Table 7. Crab Management Area H 2009 to 2013 results of the proportion model using fishery-dependent (FD) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 14b). The predictable variables 'days' and 'days²' were significant. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the proportion values; Start Date and End Date = estimated start and end dates of the time period when proportions were at, or above, the particular reduction level from the peak proportion; Start to End Length = number of days from the estimated start to end dates; Peak / or Start and End Date Variability = 95% CI around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	Prop of Soft LM			Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
		L95%		U95%							
H	Peak	0.35	0.48	0.53		Mar 05		0	0	0.4568	1324
	0.95*Peak	0.34	0.46	0.50	Jan 29		Apr 17	80	0		
	0.90*Peak	0.32	0.44	0.53	Jan 06		May 04	118	0		
	0.85*Peak	0.31	0.41	0.50	Dec 28		May 17	140	0		
	0.75*Peak	0.27	0.36	0.43	Dec 03		Jun 07	187	11		
	0.50*Peak	0.19	0.26	0.33	Oct 20		Jul 21	273	10		

*Table 8. Crab Management Area H 2009 to 2013 results of the CPUE model using fishery-independent (FI) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 16a). The predictable variables "days" and "days^2" were significant. (Peak= maximum relative abundance and date of maximum relative abundance; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak relative abundance, or 95%, 90%, 85%, 75% and 50% of the peak relative abundance, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the relative abundance values; Start Date and End Date = estimated start and end dates of the time period when the relative abundances were at, or above, the particular reduction level from the peak relative abundance; Start to End Length = number of days from the estimated start to end dates (note this value does not change); Peak / or Start and End Date Variability = 95% CI bounds around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	S-CPUE of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
H	Peak	0.24	0.44	0.69		Mar 27		1	13	0.1117	242
	0.95*Peak	0.22	0.42	0.66	Mar 02		Apr 23	53	14		
	0.90*Peak	0.21	0.40	0.62	Feb 19		May 03	74	14		
	0.85*Peak	0.20	0.37	0.59	Feb 11		May 11	90	15		
	0.75*Peak	0.18	0.33	0.52	Jan 28		May 25	118	16		
	0.50*Peak	0.12	0.22	0.35	Dec 29		Jun 24	178	17		

*Table 9. Crab Management Area H 2009 to 2013 results of the CPUE model using fishery-dependent (FD) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 16b). The predictable variables "days" and "days^2" were significant. (Peak= maximum relative abundance and date of maximum relative abundance; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak relative abundance, or 95%, 90%, 85%, 75% and 50% of the peak relative abundance, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the relative abundance values; Start Date and End Date = estimated start and end dates of the time period when the relative abundances were at, or above, the particular reduction level from the peak relative abundance; Start to End Length = number of days from the estimated start to end dates (note this value does not change); Peak / or Start and End Date Variability = 95% CI bounds around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	S-CPUE of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
H	Peak	0.17	0.50	0.88		Mar 15		1	21	0.2112	164
	0.95*Peak	0.16	0.47	0.83	Feb 16		Apr 15	59	23		
	0.90*Peak	0.15	0.45	0.79	Feb 05		Apr 27	82	24		
	0.85*Peak	0.15	0.42	0.74	Jan 26		May 06	101	25		
	0.75*Peak	0.13	0.37	0.66	Jan 11		May 21	131	26		
	0.50*Peak	0.09	0.25	0.44	Dec 09		Jun 22	196	28		

*Table 10. Summary of all model results for Crab Management Area H. The predictable variables "days" and "days^2" were significant for all sampling programs and analysis methods. (S-CPUE = standardized CPUE; FI = fishery-independent sampling program; FD = fishery-dependent sampling program; Peak Value = maximum proportion or relative abundance; Peak Date= date of maximum proportion or relative abundance; 95% CI = 95% credible intervals; 0.90*Peak = 10% reduction from the peak value, or 90% of the peak value; Date Range = estimated start and end dates of the time period when the proportions or relative abundances were at, or above, the particular reduction level from the peak proportion or relative abundance).*

CM Area	Type of Data Analysis	Sampling Program	PEAK			0.90*PEAK		
			Value	Date	95% CI (± days)	Value	Date Range	95% CI (± days)
H	Proportion (Table 6 & 7, Figure 14)	FI	0.54 ± 0.16	Mar 15	5	0.48 ± 0.15	Jan 23 - May 7	10
		FD	0.48 ± 0.12	Mar 5	6	0.44 ± 0.11	Jan 6 - May 4	8
	S-CPUE (Table 8 & 9, Figure 16)	FI	0.44 ± 0.20	Mar 27	13	0.40 ± 0.22	Feb 19 - May 3	14
		FD	0.50 ± 0.33	Mar 15	21	0.45 ± 0.30	Feb 5 - Apr 27	24

*Table 11. Crab Management Area E-S 2009 to 2013 results of the proportion model using fishery-independent (FI) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 19a). The predictable variables "days" and "days^2" were significant. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the proportion values; Start Date and End Date = estimated start and end dates of the time period when proportions were at, or above, the particular reduction level from the peak proportion; Start to End Length = number of days from the estimated start to end dates; Peak / or Start and End Date Variability = 95% CI around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	Prop of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
E-S	Peak	0.53	**0.65**	0.75		**Mar 12**		**1**	**9**	0.4427	70
	0.95*Peak	0.51	**0.61**	0.71	**Jan 31**		**Apr 23**	83	**11**		
	0.90*Peak	0.48	**0.58**	0.68	**Jan 15**		**May 10**	116	**12**		
	0.85*Peak	0.45	**0.55**	0.64	**Jan 02**		**May 22**	141	**14**		
	0.75*Peak	0.40	**0.48**	0.56	**Dec 14**		**Jun 10**	179	**15**		
	0.50*Peak	0.27	**0.32**	0.38	**Nov 06**		**Jul 18**	255	**16**		

*Table 12. Crab Management Area E-S 2009 to 2013 results of the proportion model using fishery-dependent (FD) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 19b). The predictable variables "days" and "days^2" were significant. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the proportion values; Start Date and End Date = estimated start and end dates of the time period when proportions were at, or above, the particular reduction level from the peak proportion; Start to End Length = number of days from the estimated start to end dates; Peak / or Start and End Date Variability = 95% CI around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	Prop of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
E-S	Peak	0.50	0.59	0.67		Mar 09		1	10	0.2591	54
	0.95*Peak	0.48	0.56	0.63	Jan 19		Apr 29	101	11		
	0.90*Peak	0.45	0.53	0.60	Dec 30		May 19	141	12		
	0.85*Peak	0.43	0.50	0.57	Dec 14		Jun 03	172	13		
	0.75*Peak	0.38	0.44	0.50	Nov 20		Jun 28	221	15		
	0.50*Peak	0.25	0.29	0.33	Oct 02		Aug 15	318	NA		

*Table 13. Crab Management Area E-S 2009 to 2013 results of the CPUE model using fishery-independent (FI) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 21a). The predictable variables "days" and "days^2" were significant. (Peak= maximum relative abundance and date of maximum relative abundance; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak relative abundance, or 95%, 90%, 85%, 75% and 50% of the peak relative abundance, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the relative abundance values; Start Date and End Date = estimated start and end dates of the time period when the relative abundances were at, or above, the particular reduction level from the peak relative abundance; Start to End Length = number of days from the estimated start to end dates (note this value does not change); Peak / or Start and End Date Variability = 95% CI bounds around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	S-CPUE of Soft LM			Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
		L95%		U95%							
E-S	Peak	0.19	0.43	0.74		Mar 14		1	31	0.2723	70
	0.95*Peak	0.18	0.40	0.71	Feb 19		Apr 12	53	32		
	0.90*Peak	0.17	0.39	0.67	Feb 08		Apr 22	74	32		
	0.85*Peak	0.16	0.38	0.63	Jan 31		May 01	91	33		
	0.75*Peak	0.14	0.32	0.50	Jan 16		May 15	120	34		
	0.50*Peak	0.09	0.21	0.37	Dec 16		Jun 14	181	36		

Table 14. Summary of all model results for Crab Management Area E-S. The predictable variables 'days' and 'days^{2}' were significant for all sampling programs and analysis methods. (S-CPUE = standardized CPUE; FI = fishery-independent sampling program; FD = fishery-dependent sampling program; Peak Value = maximum proportion or relative abundance; Peak Date= date of maximum proportion or relative abundance; 95% CI = 95% credible intervals; ≥ 90%Peak = 10% reduction from the peak value; or 90% of the peak value; Date Range = estimated start and end dates of the time period when the proportions or relative abundances were at, or above, the particular reduction level from the peak proportion or relative abundance).

CMI Area	Type of Data Analysis	Sampling Program	PEAK			≥ 90%PEAK		
			Value	Date	95% CI (± days)	Value	Date Range	95% CI (± days)
E-S	Proportion (Table 11 & 15, Figure 19)	FI	≥ 0.60 ± ≥ 0.11	Mar 1-2	3	≥ 0.58 ± ≥ 0.13	Jan 15 - May 19	1-2
		FD	≥ 0.59 ± ≥ 0.09	Mar 9	1-3	≥ 0.53 ± ≥ 0.08	Dec 30 - May 19	1-2
	S-CPUE (Table 15, Figure 21)	FI	≥ 0.43 ± ≥ 0.29	Mar 1-9	3-11	≥ 0.38 ± ≥ 0.25	Feb 9 - Apr 30	30
		FD	N/A	N/A	N/A	N/A	N/A	N/A

*Table 15. Crab Management Area E-1 2009 to 2013 results of the proportion model using fishery-independent (FI) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 24a). The predictable variables "days" and "days^2" were significant. (Peak = maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the proportion values; Start Date and End Date = estimated start and end dates of the time period when proportions were at, or above, the particular reduction level from the peak proportion; Start to End Length = number of days from the estimated start to end dates; Peak / or Start and End Date Variability = 95% CI around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	Prop of Soft LM			Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
		L95%		U95%							
E-1	Peak	0.30	0.48	0.67		Mar 21		1	10	0.3226	77
	0.95*Peak	0.29	0.45	0.64	Feb 11		Apr 30	79	13		
	0.90*Peak	0.27	0.43	0.60	Jan 28		May 16	111	14		
	0.85*Peak	0.25	0.41	0.57	Jan 14		May 28	135	15		
	0.75*Peak	0.23	0.36	0.50	Dec 24		Jun 18	177	17		
	0.50*Peak	0.15	0.24	0.33	Nov 13		Jul 29	259	20		

*Table 16. Crab Management Area E-T 2009 to 2013 results of the proportion model using fishery-dependent (FD) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 24b). The predictable variables "days" and "days^2" were significant. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the proportion values; Start Date and End Date = estimated start and end dates of the time period when proportions were at, or above, the particular reduction level from the peak proportion; Start to End Length = number of days from the estimated start to end dates; Peak / or Start and End Date Variability = 95% CI around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	Prop of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
E-T	Peak	0.37	0.48	0.58		Mar 24		1	8	0.4134	60
	0.95*Peak	0.35	0.46	0.55	Feb 12		May 06	84	9		
	0.90*Peak	0.33	0.43	0.52	Jan 26		May 23	118	10		
	0.85*Peak	0.32	0.41	0.49	Jan 13		Jun 05	144	11		
	0.75*Peak	0.28	0.36	0.43	Dec 22		Jun 26	187	12		
	0.50*Peak	0.19	0.24	0.29	Nov 09		Aug 09	274	15		

*Table 17. Crab Management Area E-T 2009 to 2013 results of the CPUE model using fishery-independent (FI) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 26a). The predictable variables "days" and "days^2" were significant. (Peak= maximum relative abundance and date of maximum relative abundance; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak relative abundance, or 95%, 90%, 85%, 75% and 50% of the peak relative abundance, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the relative abundance values; Start Date and End Date = estimated start and end dates of the time period when the relative abundances were at, or above, the particular reduction level from the peak relative abundance; Start to End Length = number of days from the estimated start to end dates (note this value does not change); Peak / or Start and End Date Variability = 95% CI bounds around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	S-CPUE of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
E-T	Peak	0.21	0.48	0.80		Apr 15		1	20	0.0096	77
	0.95*Peak	0.20	0.46	0.76	Mar 24		May 09	47	21		
	0.90*Peak	0.19	0.44	0.72	Mar 14		May 18	66	21		
	0.85*Peak	0.18	0.41	0.68	Mar 07		May 26	81	22		
	0.75*Peak	0.16	0.36	0.60	Feb 23		Jun 07	105	23		
	0.50*Peak	0.11	0.24	0.40	Jan 27		Jul 03	158	25		

*Table 18. Crab Management Area E-T 2009 to 2013 results of the CPUE model using fishery-dependent (FD) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 26b). The predictable variables "days" and "days^2" were significant. (Peak= maximum relative abundance and date of maximum relative abundance; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak relative abundance, or 95%, 90%, 85%, 75% and 50% of the peak relative abundance, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the relative abundance values; Start Date and End Date = estimated start and end dates of the time period when the relative abundances were at, or above, the particular reduction level from the peak relative abundance; Start to End Length = number of days from the estimated start to end dates (note this value does not change); Peak / or Start and End Date Variability = 95% CI bounds around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	S-CPUE of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
E-T	Peak	0.17	**0.49**	0.88		Mar 17		1	25	0.2981	60
	0.95*Peak	0.16	**0.47**	0.84	Feb 23		Apr 11	48	27		
	0.90*Peak	0.15	**0.44**	0.79	Feb 14		Apr 21	67	27		
	0.85*Peak	0.14	**0.42**	0.75	Feb 06		Apr 28	82	28		
	0.75*Peak	0.12	**0.37**	0.66	Jan 24		May 11	108	28		
	0.50*Peak	0.08	**0.25**	0.44	Dec 28		Jun 06	161	30		

*Table 19. Summary of all model results for Crab Management Area E-T. The predictable variables "days" and "days^2" were significant for all sampling programs and analysis methods. (S-CPUE = standardized CPUE; FI = fishery-independent sampling program; FD = fishery-dependent sampling program; Peak Value = maximum proportion or relative abundance; Peak Date= date of maximum proportion or relative abundance; 95% CI = 95% credible intervals; 0.90*Peak = 10% reduction from the peak value, or 90% of the peak value; Date Range = estimated start and end dates of the time period when the proportions or relative abundances were at, or above, the particular reduction level from the peak proportion or relative abundance).*

CM Area	Type of Data Analysis	Sampling Program	PEAK			0.90*PEAK		
			Value	Date	95% CI (± days)	Value	Date Range	95% CI (± days)
E-T	Proportion (Table 15 & 16, Figure 24)	FI	0.48 ± 0.19	Mar 21	10	0.43 ± 0.17	Jan 26 - May 16	14
		FD	0.48 ± 0.11	Mar 24	8	0.43 ± 0.10	Jan 26 - May 23	10
	S-CPUE (Table 17 & 18, Figure 26)	FI	0.48 ± 0.30	Apr 15	20	0.44 ± 0.27	Mar 14 - May 18	21
		FD	0.49 ± 0.36	Mar 17	25	0.44 ± 0.32	Feb 14 - Apr 21	27

*Table 20. Crab Management Area G 2009 to 2013 results of the proportion model using fishery-independent (FI) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 29a). The predictable variables "days" and "days^2" were significant. (Peak = maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the proportion values; Start Date and End Date = estimated start and end dates of the time period when proportions were at, or above, the particular reduction level from the peak proportion; Start to End Length = number of days from the estimated start to end dates; Peak / or Start and End Date Variability = 95% CI around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	Prop of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
G	Peak	0.46	0.69	0.88		Mar 24		1	5	0.6274	97
	0.95*Peak	0.46	0.65	0.83	Feb 19		Apr 28	70	13		
	0.90*Peak	0.43	0.62	0.79	Feb 05		May 12	97	16		
	0.85*Peak	0.41	0.58	0.74	Jan 25		May 22	118	18		
	0.75*Peak	0.36	0.52	0.66	Jan 10		Jun 07	149	20		
	0.50*Peak	0.24	0.34	0.44	Dec 11		Jul 07	209	20		

*Table 21. Crab Management Area G 2009 to 2013 results of the proportion model using fishery-dependent (FD) data for soft shell legal-sized male (LM) Dungeness Crabs (see Figure 28b). The predictable variables "days" and "days^2" were significant. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively; L95% and U95% = the lower and upper 95% credible interval (CI)) bounds, respectively, for the proportion values; Start Date and End Date = estimated start and end dates of the time period when proportions were at, or above, the particular reduction level from the peak proportion; Start to End Length = number of days from the estimated start to end dates; Peak / or Start and End Date Variability = 95% CI around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	Prop of Soft LM			Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
		L95%		U95%							
G	Peak	0.44	0.53	0.63		Mar 21		1	0	0.95/19	23
	0.95*Peak	0.42	0.50	0.76	Feb 19		Apr 22	63	18		
	0.90*Peak	0.40	0.57	0.72	Feb 27		May 04	97	10		
	0.85*Peak	0.37	0.54	0.68	Jan 29		May 10	100	13		
	0.75*Peak	0.33	0.47	0.60	Jan 13		May 28	138	14		
	0.50*Peak	0.22	0.31	0.40	Dec 19		Jun 28	193	15		

*Table 22. Crab Management Area G 2009 to 2013 results of the CPUE model using fishery-independent (FI) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 31a). The predictable variables "days" and "days^2" were significant. (Peak= maximum relative abundance and the of maximum relative abundance; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak relative abundance, or 95%, 90%, 85%, 75% and 50% of the peak relative abundance, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the relative abundance values; Start Date and End Date = estimated start and end dates of the time period when the relative abundances were at, or above, the particular reduction level from the peak relative abundance; Start to End Length = number of days from the estimated start to end dates (note this value does not change); Peak / or Start and End Date Variability = 95% CI bounds around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	S-CPUE of Soft LM			Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
		L95%		U95%							
G	Peak	0.13	0.48	0.91		Mar 24		1	16	0.1852	97
	0.95*Peak	0.12	0.43	0.85	Mar 03		Apr 17	46	20		
	0.90*Peak	0.12	0.41	0.82	Feb 21		Apr 28	66	21		
	0.85*Peak	0.11	0.39	0.77	Feb 14		May 03	79	22		
	0.75*Peak	0.10	0.34	0.68	Feb 02		May 15	103	23		
	0.50*Peak	0.06	0.23	0.45	Jan 07		Jun 10	155	24		

*Table 23. Crab Management Area G 2009 to 2013 results of the CPUE model using fishery-dependent (FD) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 31b). The predictable variables "days" and "days^2" were significant. (Peak= maximum relative abundance and date of maximum relative abundance; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak relative abundance, or 95%, 90%, 85%, 75% and 50% of the peak relative abundance, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the relative abundance values; Start Date and End Date = estimated start and end dates of the time period when the relative abundances were at, or above, the particular reduction level from the peak relative abundance; Start to End Length = number of days from the estimated start to end dates (note this value does not change); Peak / or Start and End Date Variability = 95% CI bounds around the peak date, or around both the start and end dates).*

CM Area	Model Peak & Reductions from Peak	S-CPUE of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
G	**Peak**	0.55	**0.84**	0.99		**Mar 22**		**1**	**22**	0.6557	23
	0.95*Peak	0.52	**0.79**	0.94	**Feb 20**		**Apr 22**	62	**27**		
	0.90*Peak	0.50	**0.75**	0.89	**Feb 09**		**May 03**	84	**27**		
	0.85*Peak	0.47	**0.71**	0.84	**Jan 31**		**May 11**	101	**27**		
	0.75*Peak	0.41	**0.63**	0.74	**Jan 18**		**May 24**	127	**27**		
	0.50*Peak	0.28	**0.42**	0.50	**Dec 24**		**Jun 17**	176	**28**		

*Table 24. Summary of all model results for Crab Management Area G. The predictable variables "days" and "days^2" were significant for all sampling programs and analysis methods. (S-CPUE = standardized CPUE; FI = fishery-independent sampling program; FD = fishery-dependent sampling program; Peak Value = maximum proportion or relative abundance; Peak Date= date of maximum proportion or relative abundance; 95% CI = 95% credible intervals; 0.90*Peak = 10% reduction from the peak value, or 90% of the peak value; Date Range = estimated start and end dates of the time period when the proportions or relative abundances were at, or above, the particular reduction level from the peak proportion or relative abundance).*

CM Area	Type of Data Analysis	Sampling Program	PEAK			0.90*PEAK		
			Value	Date	95% CI (± days)	Value	Date Range	95% CI (± days)
G	Proportion (Table 20 & 21, Figure 29)	FI	0.69 ± 0.20	Mar 24	5	0.62 ± 0.18	Feb 5 - May 12	16
		FD	0.63 ± 0.18	Mar 21	6	0.57 ± 0.16	Feb 7 - May 4	11
	S-CPUE (Table 22 & 23, Figure 31)	FI	0.45 ± 0.39	Mar 24	18	0.41 ± 0.35	Feb 21 – Apr 26	21
		FD	0.84 ± 0.22	Mar 22	22	0.75 ± 0.20	Feb 9 – May 3	27

*Table 25. Crab Management Area H (Nanaimo, Ganges and Sidney Index Areas combined) model fits of the proportion model using fishery-independent (FI) data by year for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 33). The predictable variables "days" and "days^2" were significant for all years. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively).*

Model Year(s)	Model Peak & Reductions from Peak	Prop of Soft LM	Start Date	End Date	Num. Days	R^2	Sample Events
	Peak	0.74	Mar 27				
	0.95*Peak	0.70	Mar 06	Apr 19	44	0.4555	45
2009	0.90*Peak	0.67	Feb 26	Apr 27	60		
(1st peak)	0.85*Peak	0.63	Feb 20	May 03	72		
	0.75*Peak	0.56	Feb 11	May 12	90		
	0.50*Peak	0.37	Jan 25	Jun 01	127		
	Peak	0.47	Aug 03				
(2nd	0.95*Peak	0.44	Jul 17	Aug 20	34		
	0.90*Peak	0.42	Jul 10	Aug 27	48		
	0.85*Peak	0.40	Jul 05	Sep 01	58		
	0.75*Peak	0.35	Jun 24	Sep 10	78		
	0.50*Peak	0.23	N/A	N/A	N/A		
	Peak	0.41	Mar 25				
	0.95*Peak	0.39	Feb 13	May 06	82	0.333	53
2010	0.90*Peak	0.37	Jan 28	May 22	114		
	0.85*Peak	0.35	Jan 15	Jun 04	140		
	0.75*Peak	0.31	Dec 25	Jun 25	182		
	0.50*Peak	0.20	Nov 10	Aug 09	272		
	Peak	0.39	Mar 10				
	0.95*Peak	0.37	Feb 12	Apr 08	55	0.414	43
2011	0.90*Peak	0.35	Jan 31	Apr 19	78		
	0.85*Peak	0.33	Jan 22	Apr 27	95		
	0.75*Peak	0.29	Jan 07	May 12	125		
	0.50*Peak	0.19	Dec 06	Jun 13	189		
	Peak	0.76	Mar 16				
	0.95*Peak	0.72	Feb 17	Apr 16	58	0.780	47
2012	0.90*Peak	0.68	Feb 06	Apr 28	81		
	0.85*Peak	0.65	Jan 28	May 06	98		
	0.75*Peak	0.57	Jan 15	May 19	124		
	0.50*Peak	0.38	Dec 23	Jun 11	170		
	Peak	0.51	Feb 06				
	0.95*Peak	0.48	Dec 25	Mar 23	88	0.356	54
2013	0.90*Peak	0.46	Dec 07	Apr 10	124		
	0.85*Peak	0.43	Nov 22	Apr 24	153		
	0.75*Peak	0.38	Oct 30	May 16	198		
	0.50*Peak	0.25	N/A	Jun 30	N/A		

*Table 26. Crab Management Area E-S (Sooke Index Area) model fits of the proportion model using fishery-independent (FI) data by year for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 34). The predictable variables "days" and "days^2" were only significant for 2009 and 2012. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively).*

Model Year(s)	Model Peak & Reductions from Peak	Prop of Soft LM	Start Date	End Date	Num. Days	R^2	Sample Events
2009	Peak	0.69	Apr 15				
	0.95*Peak	0.66	Mar 14	May 21	68	0.3214	15
	0.90*Peak	0.62	Feb 28	Jun 04	96		
	0.85*Peak	0.59	Feb 19	Jun 14	115		
	0.75*Peak	0.52	Feb 03	Jun 29	146		
	0.50*Peak	0.35	Jan 01	Jul 29	209		
2010	Peak	0.55	~~Mar 29~~		Not Significant for "Days>0"		
	0.95*Peak	0.52	Feb 11	May 16	94	0.201	18
	0.90*Peak	0.49	Jan 23	Jun 04	132		
	0.85*Peak	0.46	Jan 09	Jun 19	161		
	0.75*Peak	0.41	Dec 16	Jul 13	209		
	0.50*Peak	0.27	Oct 25	Sep 03	313		
2011	Peak	0.54	~~Jan 29~~		Not Significant for "Days>0" or "Days^2>0"		
	0.95*Peak	0.51	Dec 20	Mar 07	77	0.673	11
	0.90*Peak	0.48	Dec 02	Mar 21	109		
	0.85*Peak	0.46	Nov 16	Apr 02	137		
	0.75*Peak	0.40	Oct 17	Apr 20	185		
	0.50*Peak	0.27	N/A	May 26	N/A		
2012	Peak	0.98	Mar 23				
	0.95*Peak	0.93	Feb 13	May 06	82	0.944	11
	0.90*Peak	0.88	Feb 04	May 15	100		
	0.85*Peak	0.83	Jan 30	May 20	110		
	0.75*Peak	0.73	Jan 23	May 27	124		
	0.50*Peak	0.49	Jan 11	Jun 08	148		
2013	Peak	0.74	~~Nov 08~~		Not Significant for "Days>0" or "Days^2>0"		
	0.95*Peak	0.70	N/A	Jan 30	N/A	0.405	15
	0.90*Peak	0.66	N/A	Mar 04	N/A		
	0.85*Peak	0.63	N/A	Mar 31	N/A		
	0.75*Peak	0.55	N/A	May 13	N/A		
	0.50*Peak	0.37	N/A	Aug 04	N/A		

*Table 27. Crab Management Area E-T (Tofino Index Area) model fits of the proportion model using fishery-independent (FI) data by year for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 35). The predictable variables "days" and "days^2" were only significant for 2010, 2011 and 2012. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively).*

Model Year(s)	Model Peak & Reductions from Peak	Prop of Soft LM	Start Date	End Date	Num. Days	R^2	Sample Events
2009	Peak	0.46	May 29		Not Significant for "Days>0" or "Days^2>0"		
	0.95*Peak	0.44	Mar 27	Aug 08	134	0.1202	15
	0.90*Peak	0.42	Feb 27	Sep 06	191		
	0.85*Peak	0.40	Feb 05	Sep 29	236		
	0.75*Peak	0.35	Dec 27	Oct 01	278		
	0.50*Peak	0.23	N/A	N/A	N/A		
2010	Peak	0.47	Mar 04				
	0.95*Peak	0.44	Jan 29	Apr 10	71	0.530	17
	0.90*Peak	0.42	Jan 15	Apr 24	99		
	0.85*Peak	0.40	Jan 03	May 05	122		
	0.75*Peak	0.35	Dec 16	May 24	159		
	0.50*Peak	0.23	Nov 08	Jun 30	234		
2011	Peak	0.43	Apr 02				
	0.95*Peak	0.41	Mar 16	Apr 21	36	0.625	14
	0.90*Peak	0.39	Mar 09	Apr 28	50		
	0.85*Peak	0.37	Mar 03	May 04	62		
	0.75*Peak	0.32	Feb 22	May 13	80		
	0.50*Peak	0.21	Feb 02	Jun 01	N/A		
2012	Peak	0.88	Mar 20				
	0.95*Peak	0.84	Feb 20	Apr 20	59	0.945	14
	0.90*Peak	0.80	Feb 11	Apr 30	78		
	0.85*Peak	0.75	Feb 04	May 08	91		
	0.75*Peak	0.66	Jan 25	May 16	111		
	0.50*Peak	0.44	Jan 09	Jun 01	143		
2013	Peak	0.41	Feb 14		Not Significant for "Days>0" or "Days^2>0"		
	0.95*Peak	0.39	Dec 29	Apr 05	97	0.211	17
	0.90*Peak	0.37	Dec 08	Apr 25	138		
	0.85*Peak	0.35	Nov 20	May 10	171		
	0.75*Peak	0.31	Oct 19	Jun 04	228		
	0.50*Peak	0.21	N/A	Jul 26	N/A		

*Table 28. Crab Management Area G (Village Channel and Retreat Passage Index Areas combined) model fits of the proportion model using fishery-independent (FI) data by year for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure 36). The predictable variables "days" and "days^2" were significant for all years except 2013. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively).*

Model Year(s)	Model Peak & Reductions from Peak	Prop of Soft LM	Start Date	End Date	Num. Days	R^2	Sample Events
2009	Peak	0.74	Apr 11				
	0.95*Peak	0.71	Mar 03	May 23	81	0.8548	11
	0.90*Peak	0.67	Feb 16	Jun 08	112		
	0.85*Peak	0.63	Feb 04	Jun 20	136		
	0.75*Peak	0.56	Jan 17	Jul 07	171		
	0.50*Peak	0.37	Dec 12	Aug 09	240		
2010	Peak	0.52	Mar 08				
	0.95*Peak	0.49	Jan 29	Apr 18	79	0.511	25
	0.90*Peak	0.46	Jan 13	May 04	111		
	0.85*Peak	0.44	Dec 31	May 17	137		
	0.75*Peak	0.39	Dec 10	Jun 06	178		
	0.50*Peak	0.26	Oct 28	Jul 17	262		
2011	Peak	0.58	Mar 13				
	0.95*Peak	0.55	Feb 20	Apr 04	43	0.873	23
	0.90*Peak	0.53	Feb 11	Apr 12	60		
	0.85*Peak	0.50	Feb 05	Apr 19	73		
	0.75*Peak	0.44	Jan 25	Apr 30	95		
	0.50*Peak	0.29	Jan 04	May 20	N/A		
2012	Peak	0.85	Mar 18				
	0.95*Peak	0.81	Feb 16	Apr 19	62	0.942	23
	0.90*Peak	0.77	Feb 05	Apr 30	84		
	0.85*Peak	0.72	Jan 28	May 08	100		
	0.75*Peak	0.64	Jan 16	May 19	123		
	0.50*Peak	0.43	Dec 28	Jun 08	162		
2013	Peak	N/A	N/A		Not Significant for "Days=0" or "Days^2=0"		
	0.95*Peak	N/A	N/A	N/A	N/A	0.618	15
	0.90*Peak	N/A	N/A	N/A	N/A		
	0.85*Peak	N/A	N/A	N/A	N/A		
	0.75*Peak	N/A	N/A	N/A	N/A		
	0.50*Peak	N/A	N/A	N/A	N/A		

9 FIGURES

Figure 1. Crab management areas (CMAs) in British Columbia.

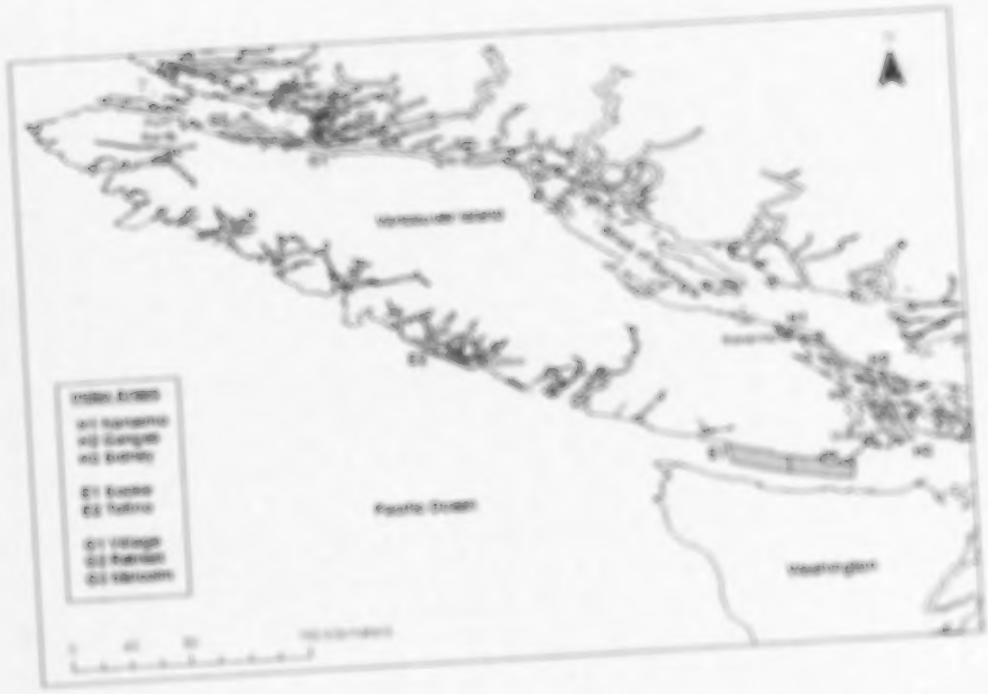


Figure 2. Dungeness Crab biological sampling index areas (in grey) in the south coast of British Columbia, 2009 to 2013. There were three index areas in Crab Management Area (CMA) H, one index area in each of CMA E-S and CMA E-T, and three index areas in CMA G.

(a) Nanaimo Index Area

(c) Sidney Index Area

(b) Georgia Index Area

Figure 3. Crab biological sampling index areas in Crab Management Area H, 2009 to 2013.

(a) Sooke Inlet Area

(b) Toffino Inlet Area

Figure 6. Crab biological sampling index areas in Crab Management Area (CMA) E, 2009 to 2013. These two index areas are referred to as CMA E-S (Sooke) and CMA E-T (Toffino).

(a) Village Channel Index Area

(c) Retreat Passage Index Area

(b) Malcolm Island Index Area

Figure 5. Crab biological sampling index areas in Crab Management Area G, 2009 to 2013.

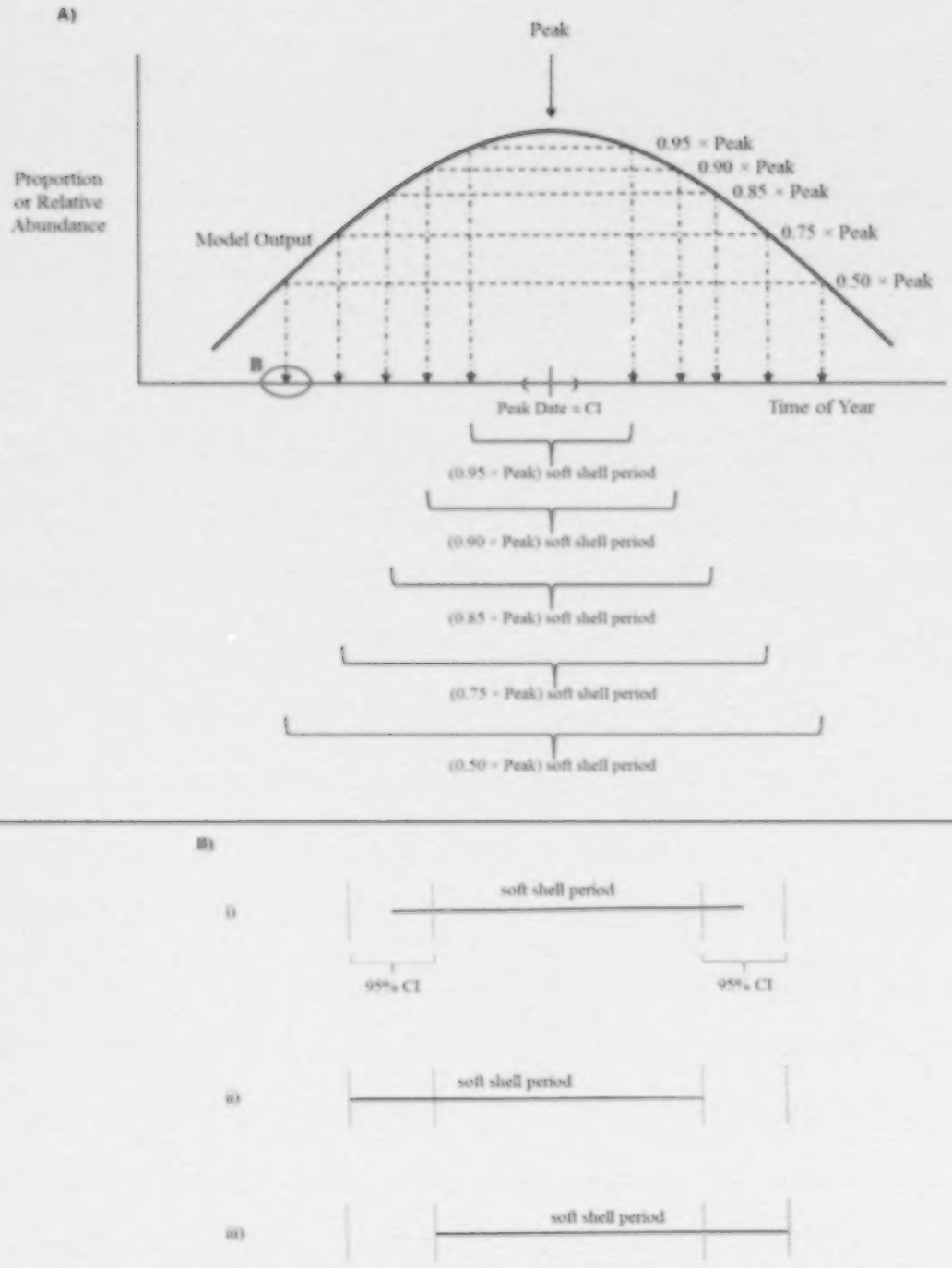


Figure 6. Illustrations describing: A) five reduction level options (from the peak value) and their corresponding dates, and B) how to interpret the 95% credible intervals (CI) associated with the start/end dates of a particular soft-shell period.

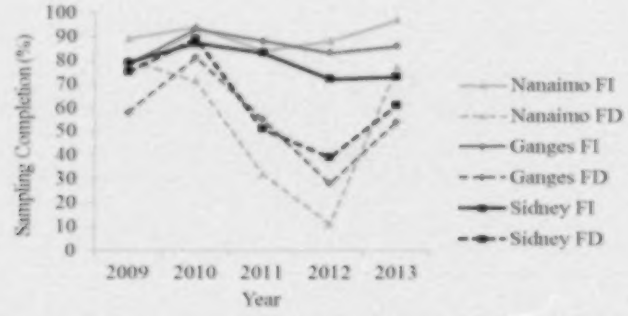


Figure 7. Service provider sampling completion in Crab Management Area H at the Nanaimo, Ganges, and Sidney Index Areas, 2009 to 2013. (FI = fishery-independent sampling; FD = fishery-dependent sampling).

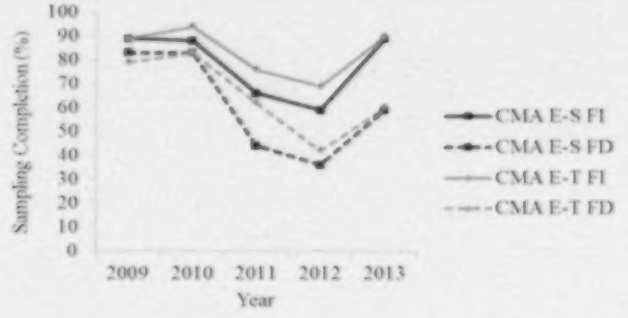


Figure 8. Service provider sampling completion in Crab Management Areas E-S (Sooke) and E-T (Tofino), 2009 to 2013. (FI = fishery-independent sampling; FD = fishery-dependent sampling).

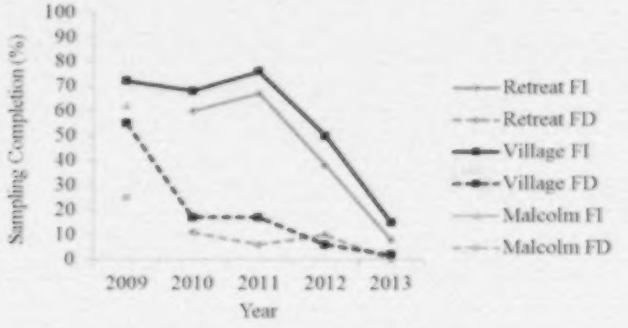


Figure 9. Service provider sampling completion in Crab Management Area G at the Retreat Passage, Village Channel, and Malcolm Island Index Areas, 2009 to 2013. (FI = fishery-independent sampling; FD = fishery-dependent sampling).

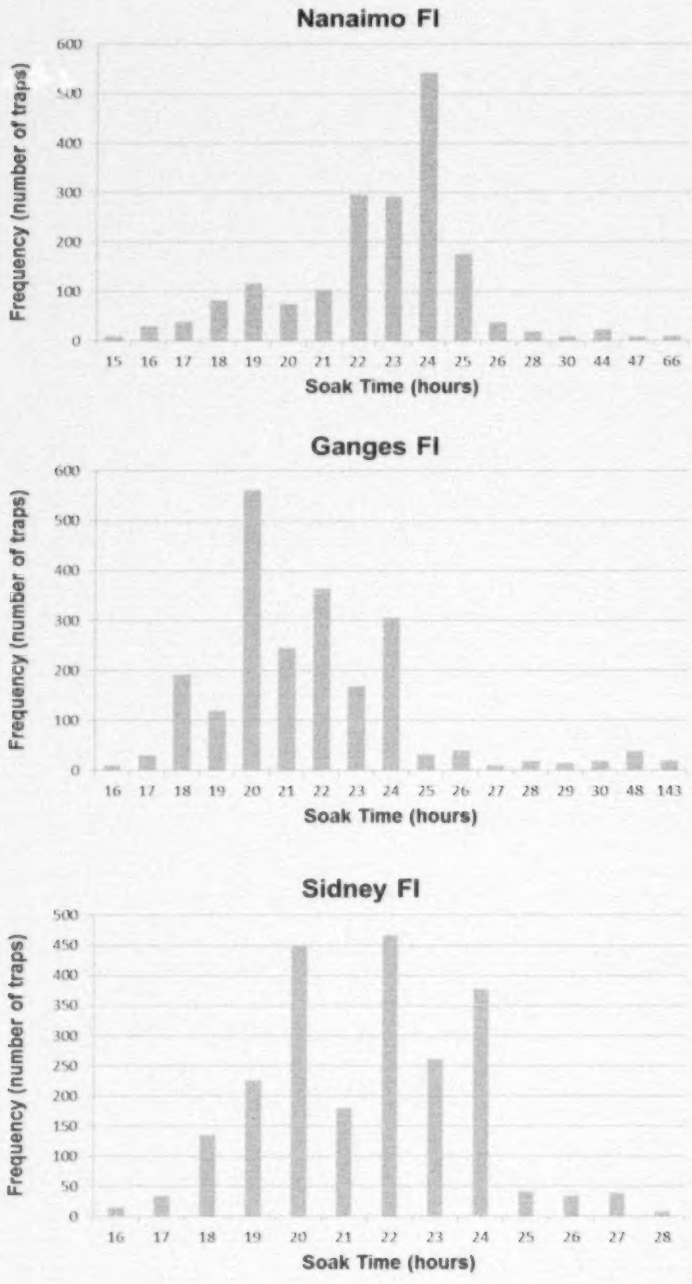


Figure 10. Crab Management Area H fishery-independent sampling program trap soak times by index area.

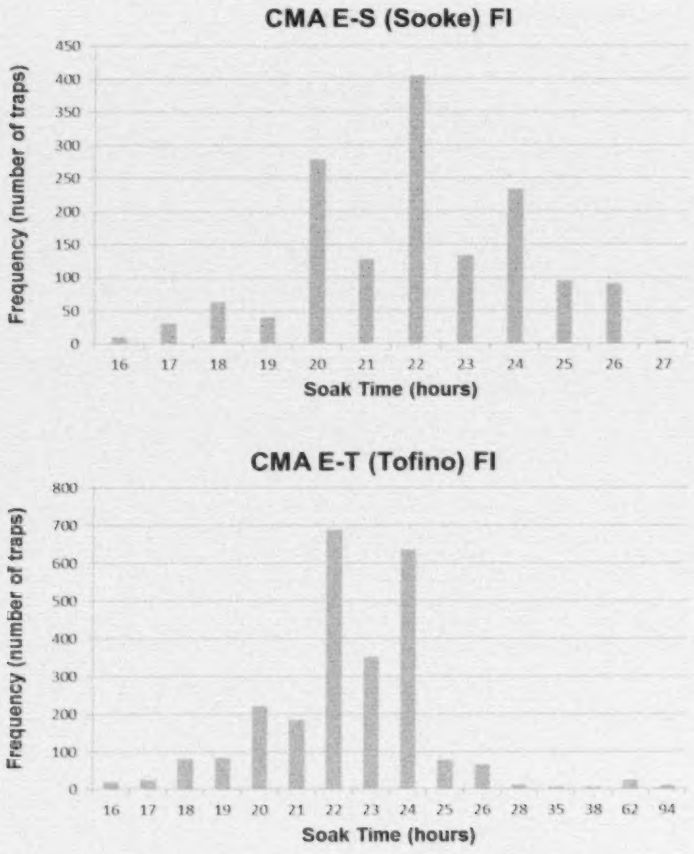


Figure 11. Crab Management Areas (CMAs) E-S and E-T fishery-independent sampling program trap soak times.

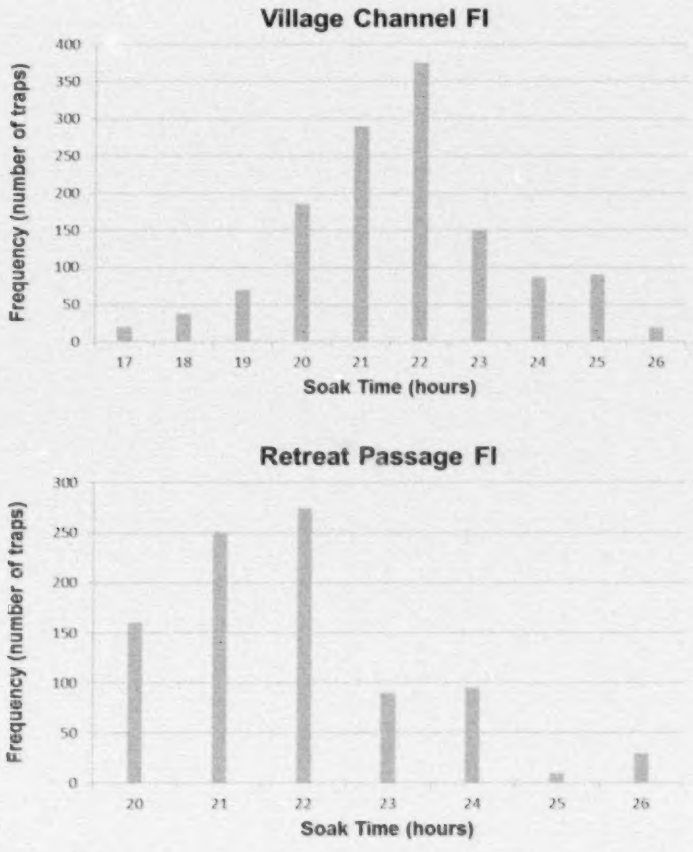


Figure 12. Crab Management Area G fishery-independent sampling program trap soak times by index area.

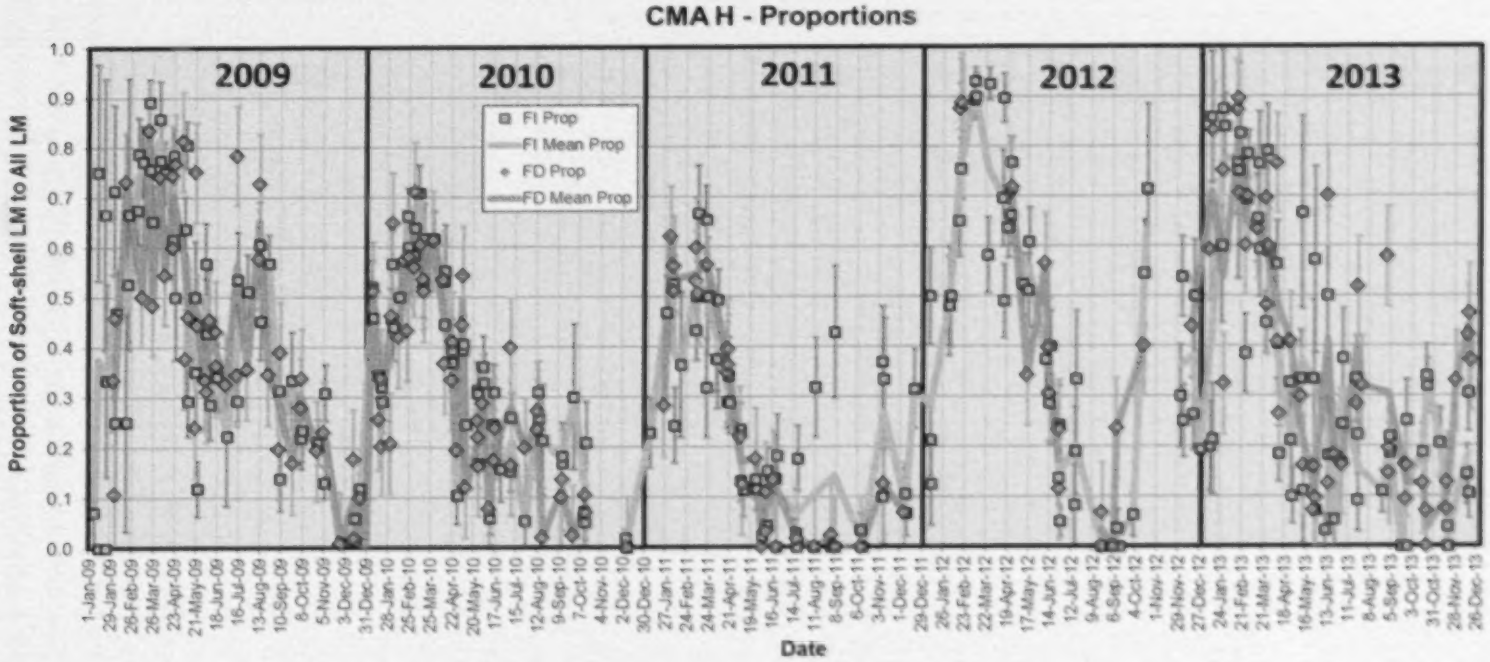


Figure 13. Crab Management Area (CMA) H 2009 to 2013 observed proportions (± SE) from the (a) fishery-independent (FI, blue) and (b) fishery-dependent (FD, red) sampling programs of soft-shell legal-sized male (LM) Dungeness Crabs of all legal-sized males per sampling event (all index areas combined). (Blue squares = FI observed data, blue line = mean of FI observed data, red diamonds = FD observed data, red line = mean of FD observed data. Note disconnected lines indicate scheduled sampling was missed between dates).

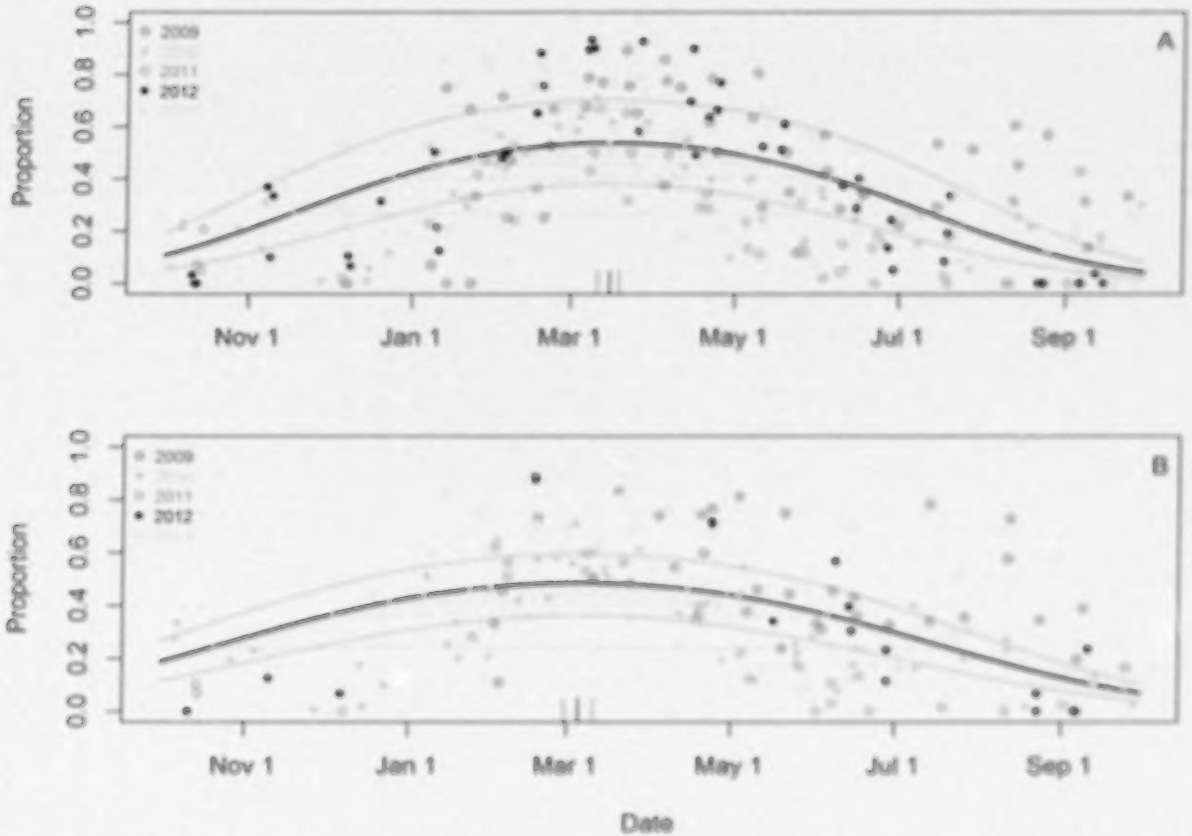


*Figure 14. Crab Management Area H 2009 to 2013 proportion model results using (a) fishery-independent (FI) and (b) fishery-dependent (FD) data for soft-shell legal-sized male Dungeness Crabs (Nanaimo, Ganges and Sidney Index Areas combined). The predictable variables "days" and "days^2" were significant. See Table 6 and Table 7 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

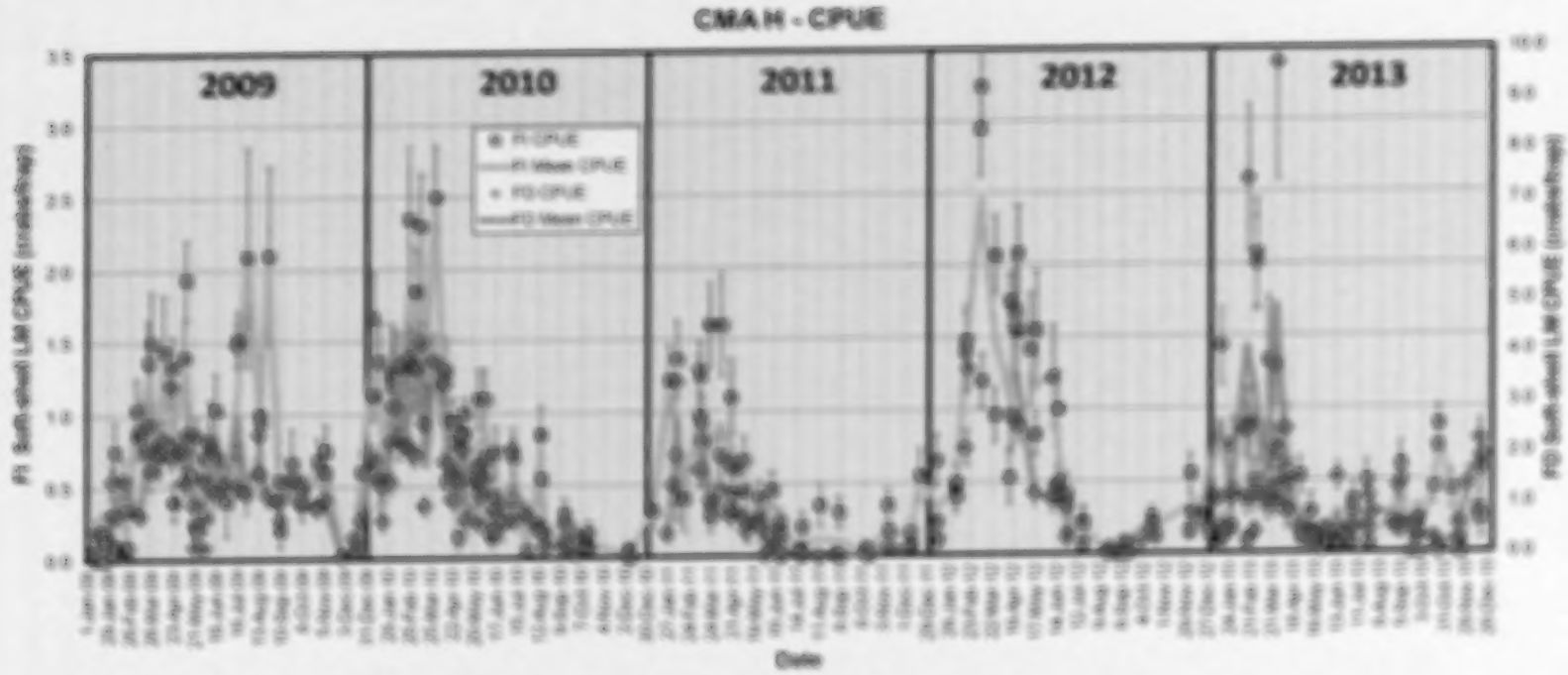


Figure 13. Crab Management Area (CMA) H 2009 to 2013 observed CPUE (± SE) from the (a) fishery-independent (FI, blue) and (b) fishery-dependent (FD, red) sampling programs of soft-shell legal-sized male (LM) Dungeness Crabs per sampling event (all index areas combined). (Blue squares = FI observed data, blue line = mean of FI observed data, red diamonds = FD observed data, red line = mean of FD observed data. Note disconnected lines indicate scheduled sampling was missed between dates, and the y-axis has a larger scale on the FD graph than on the FI graph).

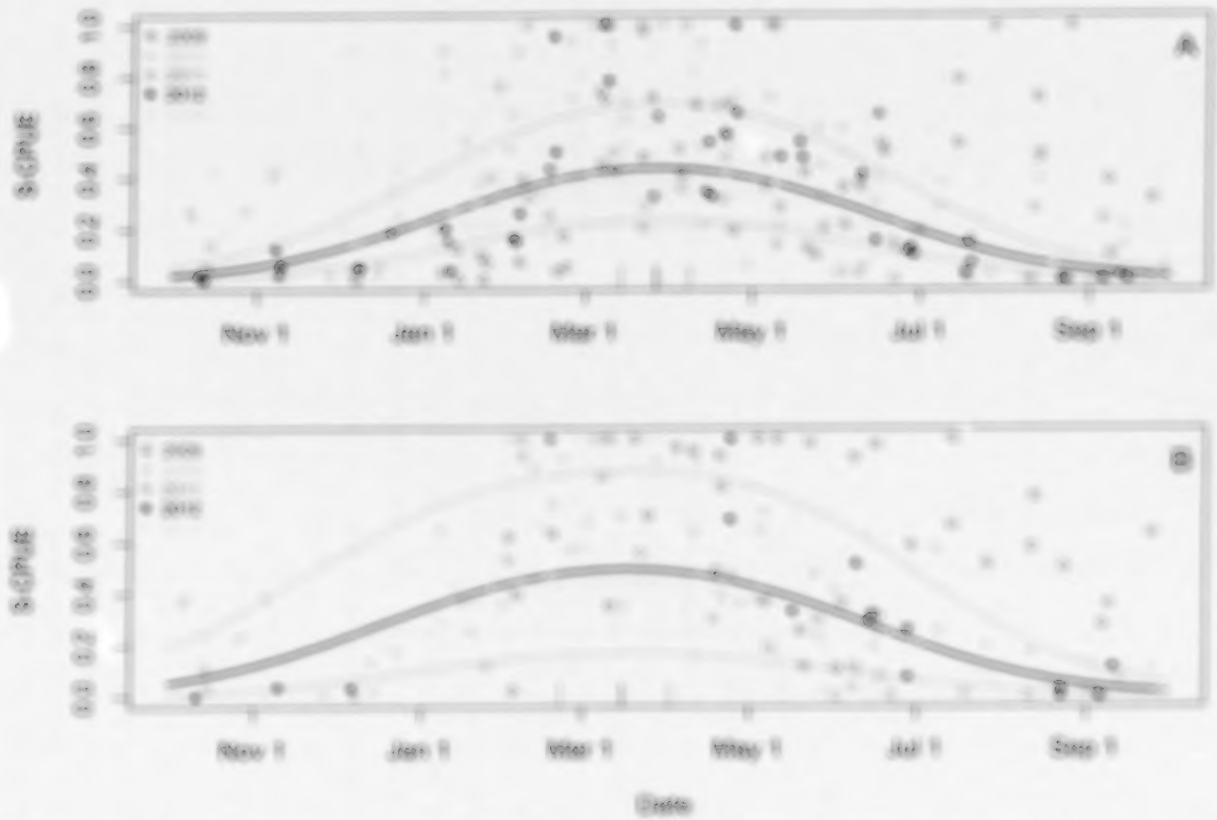
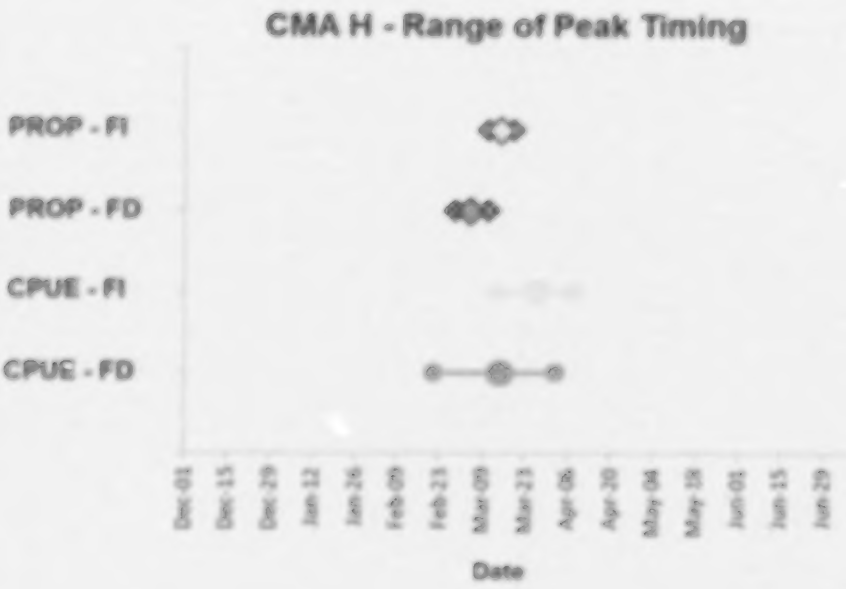


Figure 18. Crab Management Area H 2009 to 2012 CPUE model results using (a) fishery independent (FI) and (b) fishery dependent (FD) data for soft-shell legal-sized male Dungeness Crabs (Nanaimo, Georgia and Sidney Index Areas combined). The predictable variables 'days' and 'days^2' were significant. See Table 8 and Table 9 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = medians from the peak proportion from the top down, i) 95th%ile, ii) 90th%ile, iii) 85th%ile, iv) 75th%ile and v) 50th%ile, respectively; red and black vertical lines above x-axis = peak date and 95% CI).

(a)



(b)

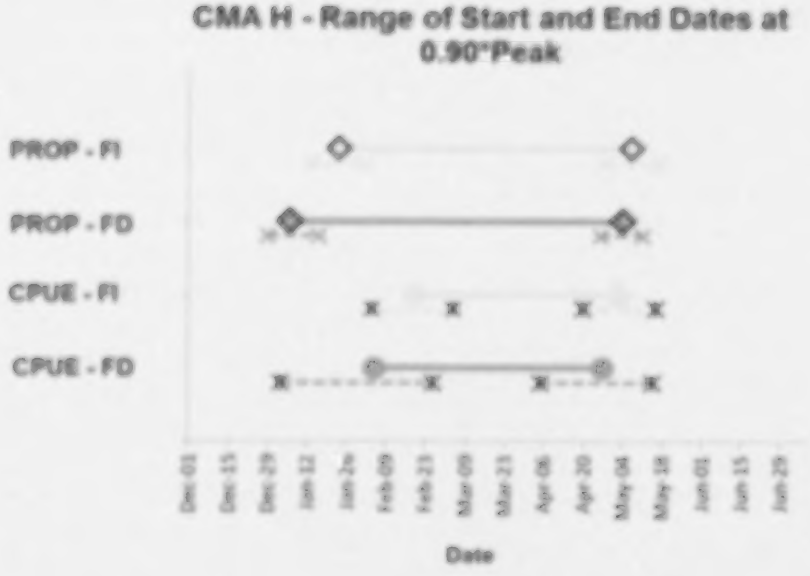


*Figure 17. Crab Management Area (CMA) H (2009 to 2013 combined data) comparisons of (a) peak date timing and 95% credible interval (CI) bounds, and (b) start and end date timing and 95% CI at 0.90*Peak for fishery-independent (FI) and fishery-dependent (FD) data using proportion and CPUE analysis methods. (Large symbols represent the peaks while the smaller symbols represent the 95% CI around the peaks; diamonds = proportion model; circles = CPUE model; blue symbols = FI data; red symbols = FD data).*

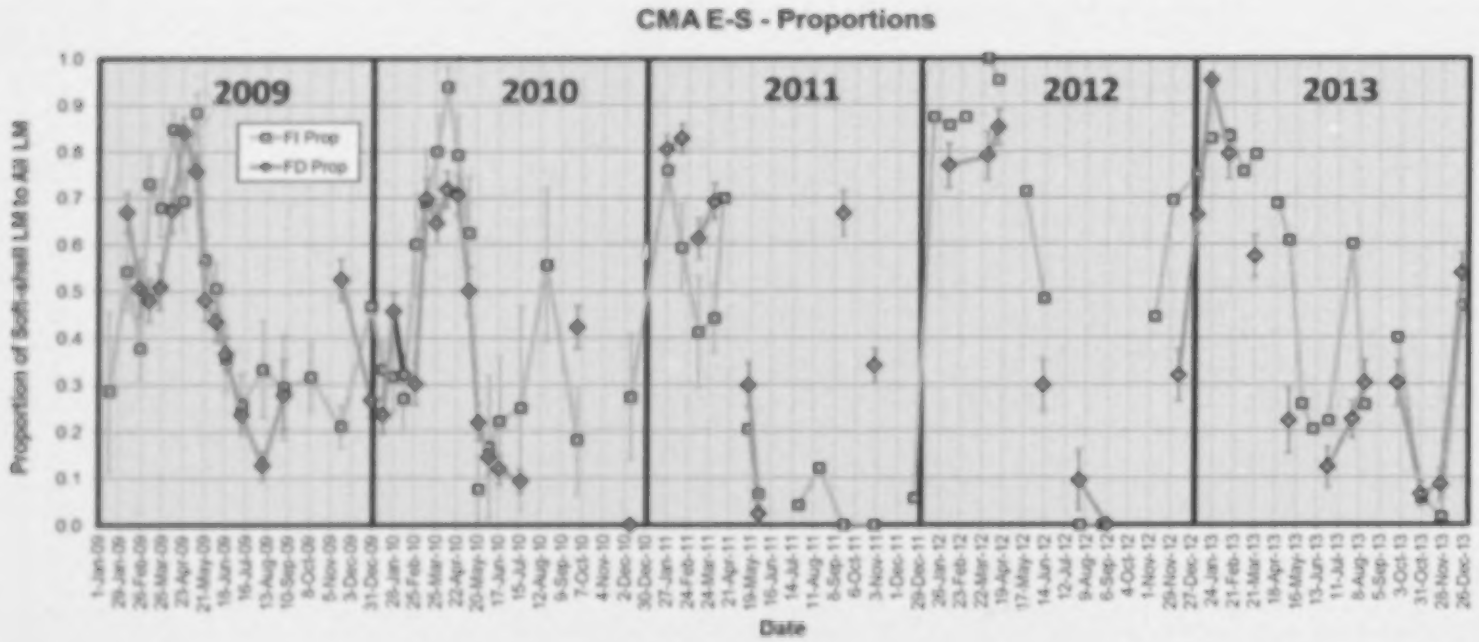


Figure 18. Crab Management Area (CMA) E-S 2009 to 2013 observed proportions from the (a) fishery-dependent (FI, blue markers and lines) and (b) fishery-dependent (FD, red markers and lines) sampling programs of soft-shell legal-sized male (LM) Dungeness Crab of all legal-sized males per sampling event (± SE).

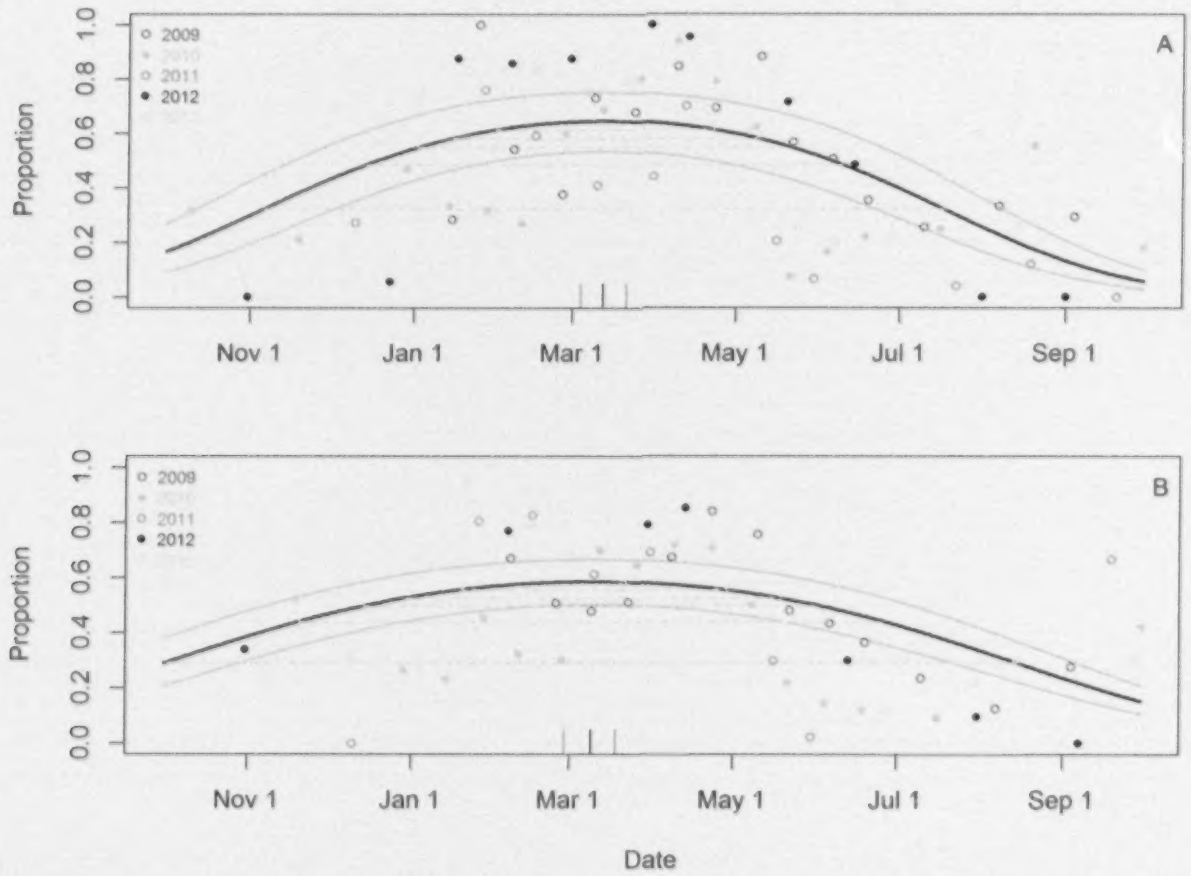


*Figure 19. Crab Management Area E-S 2009 to 2013 proportion model results using (a) fishery-independent and (b) fishery-dependent data for soft-shell legal-sized male Dungeness Crabs. The predictable variables "days" and "days^2" were significant. See Table 11 and Table 12 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

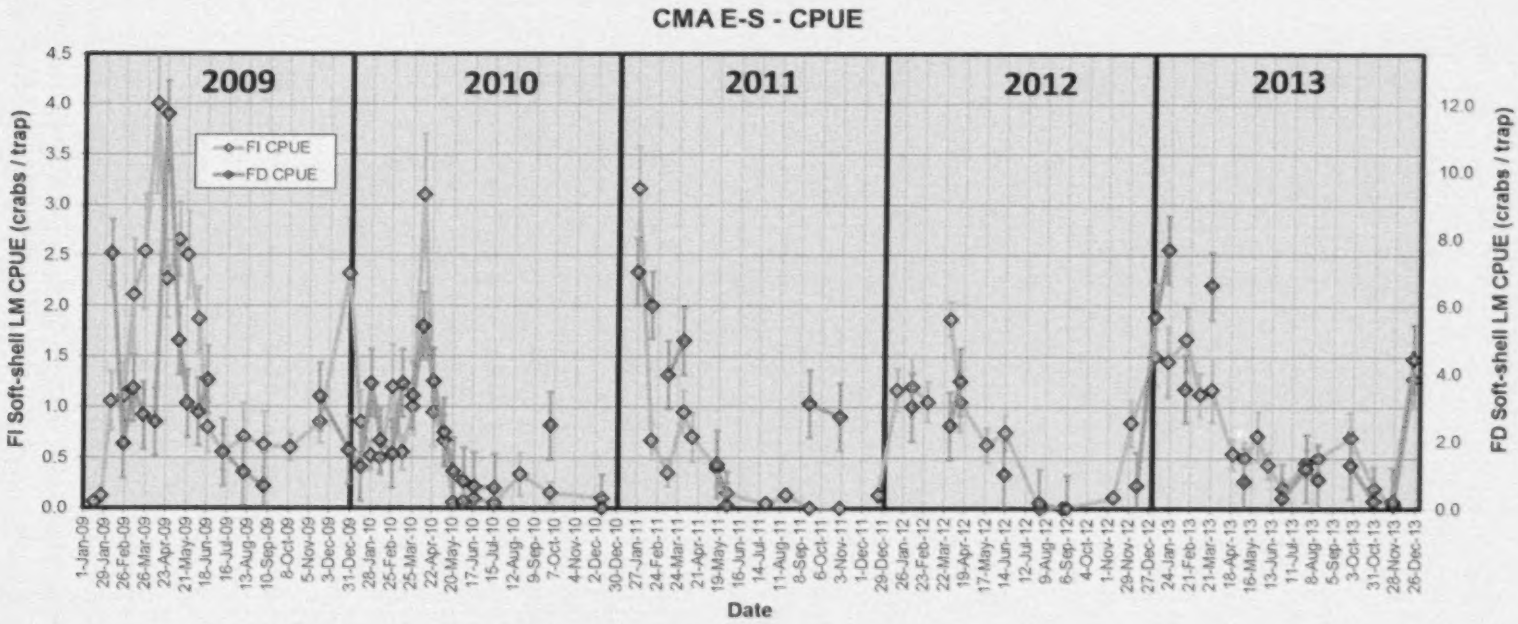


Figure 20. Crab Management Area (CMA) E-S 2009 to 2013 observed CPUE from the (a) fishery-dependent (FI, blue markers and lines) and (b) fishery-dependent (FD, red markers and lines) sampling programs of soft-shell legal-sized male (LM) Dungeness Crab per sampling event (± SE). Disconnected lines indicate a scheduled sampling was missed between dates. Note different scales for FI and FD CPUE's (y-axes).

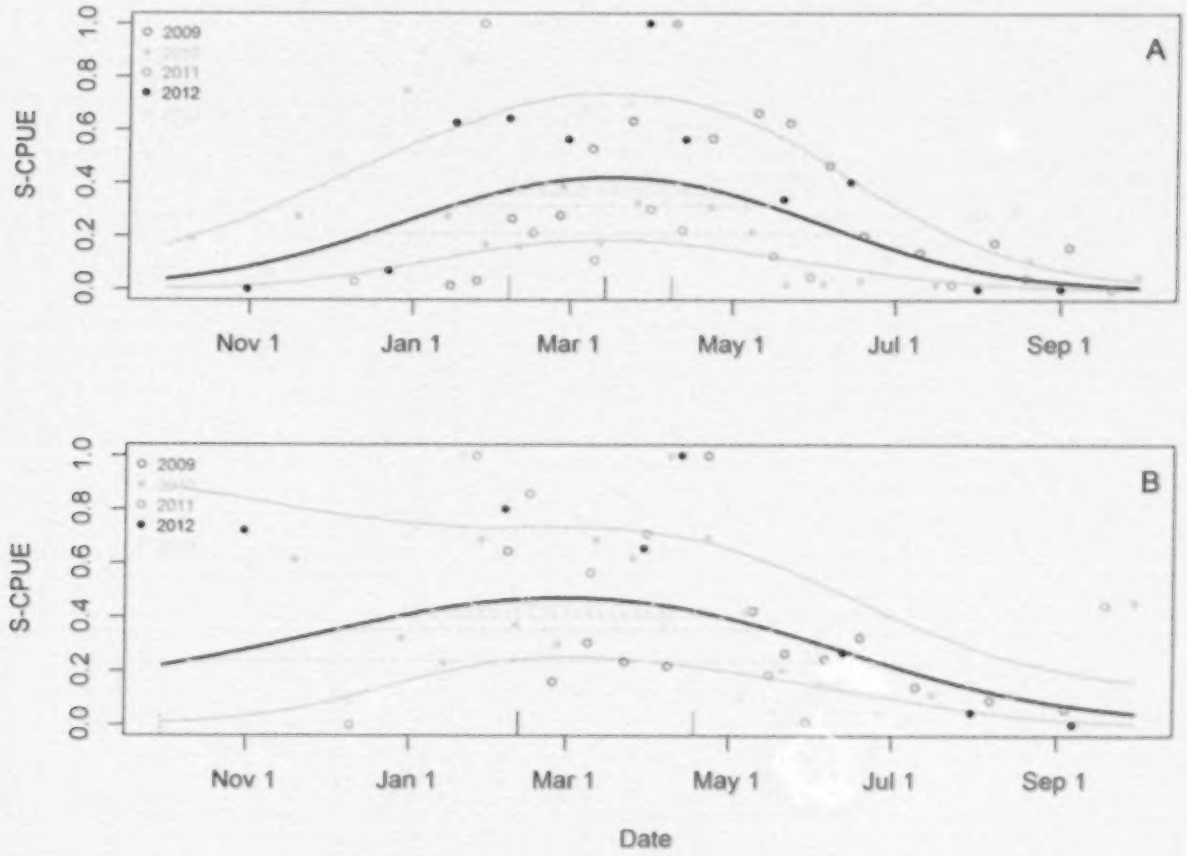
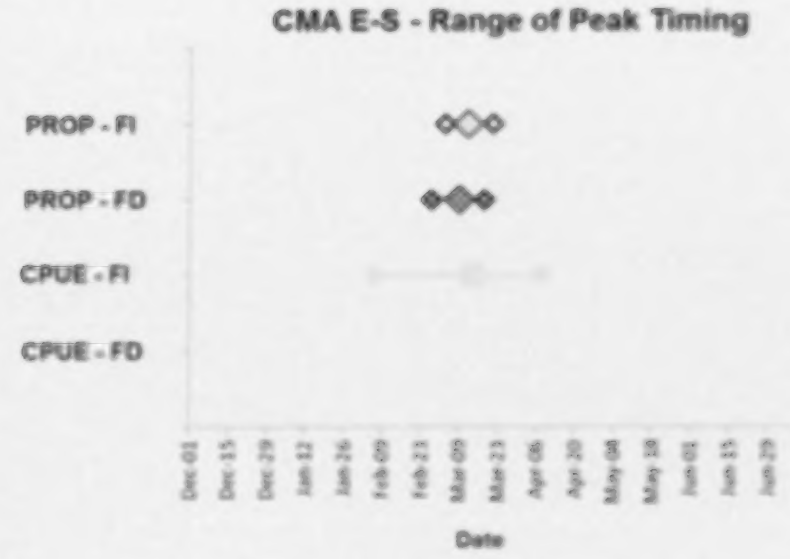


*Figure 21. Crab Management Area E-S 2009 to 2013 CPUE model results using (a) fishery-independent and (b) fishery-dependent data for soft-shell legal-sized male Dungeness Crabs. The predictable variable "days" was significant for both the FI and FD programs, but "days^2" was significant for the FI data, but not significant for the FD data (p(coef. for days>0) =0.92)). See Table 13 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

(a)



(b)

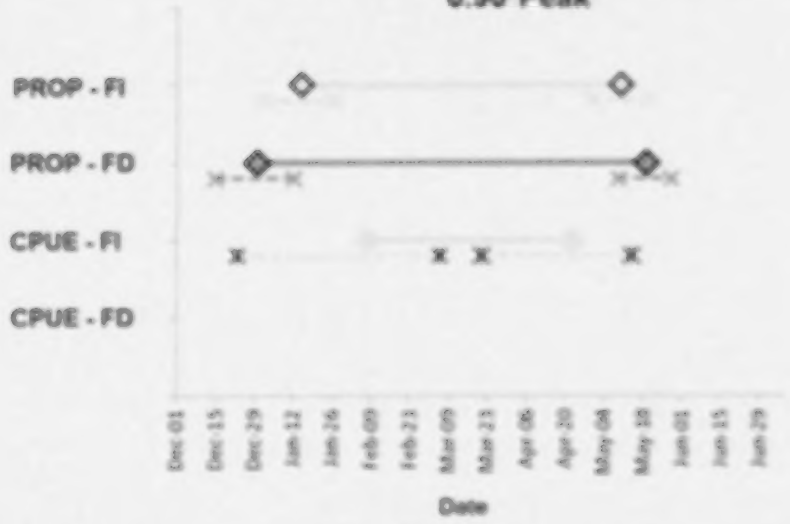


*Figure 22. Crab Management Area (CMA) E-S (2009 to 2013 combined data) comparisons of (a) peak date timing and 95% credible interval (CI) bounds, and (b) start and end date timing and 95% CI at 0.90*Peak for fishery-independent (FI) and fishery-dependent (FD) data using proportion and CPUE analysis methods. (Large symbols represent the peaks while the smaller symbols represent the 95% CI around the peaks; diamonds = proportion model; circles = CPUE model; blue symbols = FI data; red symbols = FD data).*

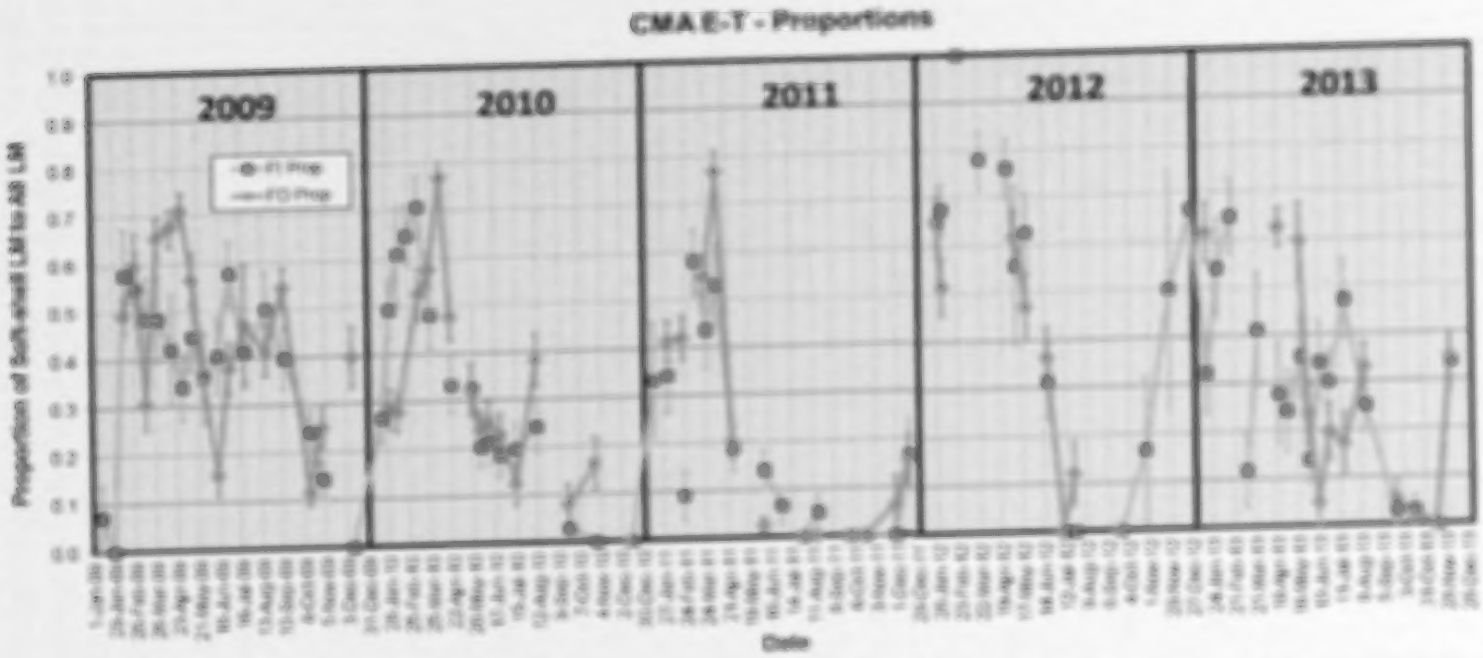


Figure 23. Crab Management Area (CMA) E-T 2009 to 2013 observed proportions from the (a) fishery-independent (FI, blue markers and lines) and (b) fishery-dependent (FD, red markers and lines) sampling programs of soft-shell legal-sized male (LM) Dungeness Crab of all legal-sized males per sampling event (± SE). Disconnected lines indicate a scheduled sampling was missed between dates.

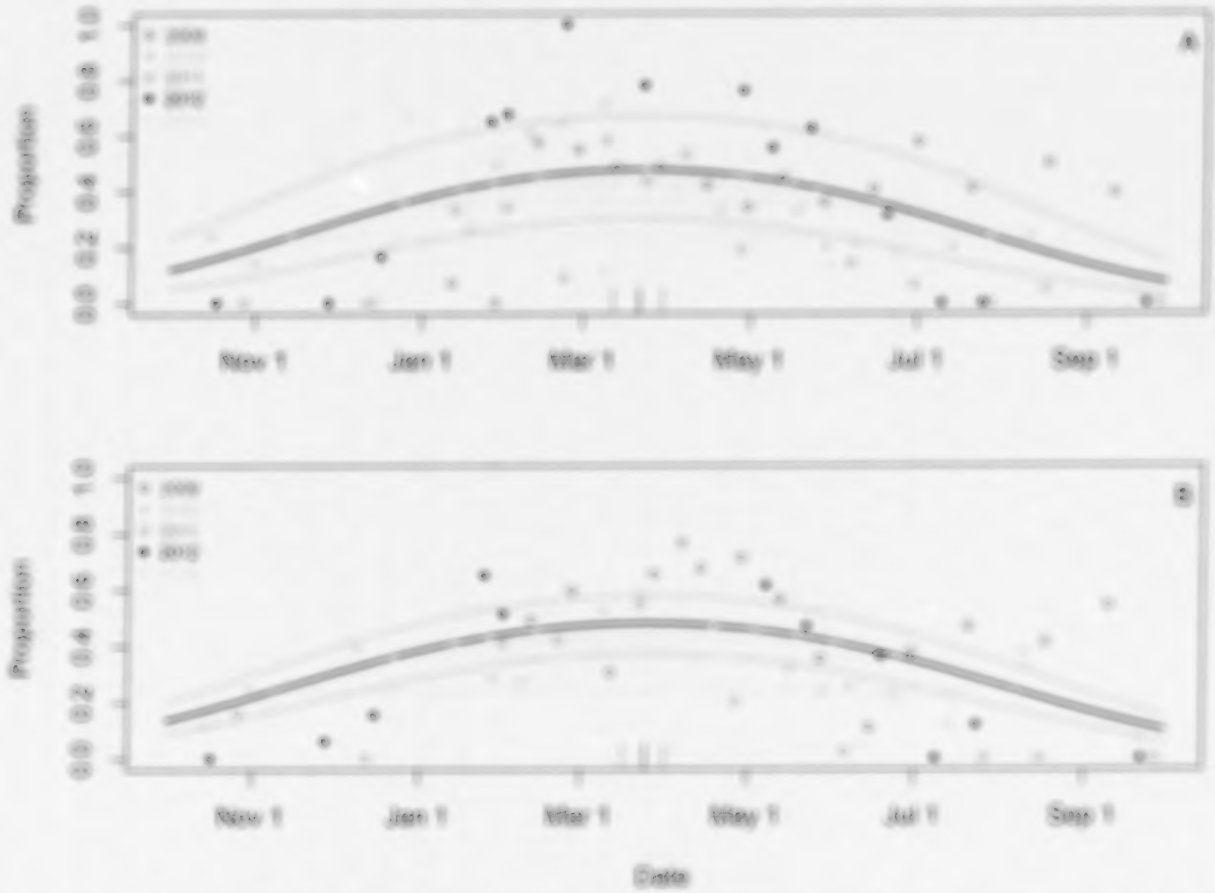


*Figure 24. Crab Management Area (CMA) E-1 2009 to 2013 proportion model results using (a) fishery-independent and (b) fishery-dependent data for soft-shell legal-sized male Dungeness Crabs. The predictable variables "days" and "days²" were significant. See Table 12 and Table 16 for details. (Red lines = 95% credible interval bounds (CI)); green dashed lines = reductions from the peak proportion, from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines drawn x-axis = peak date and 95% CI).*

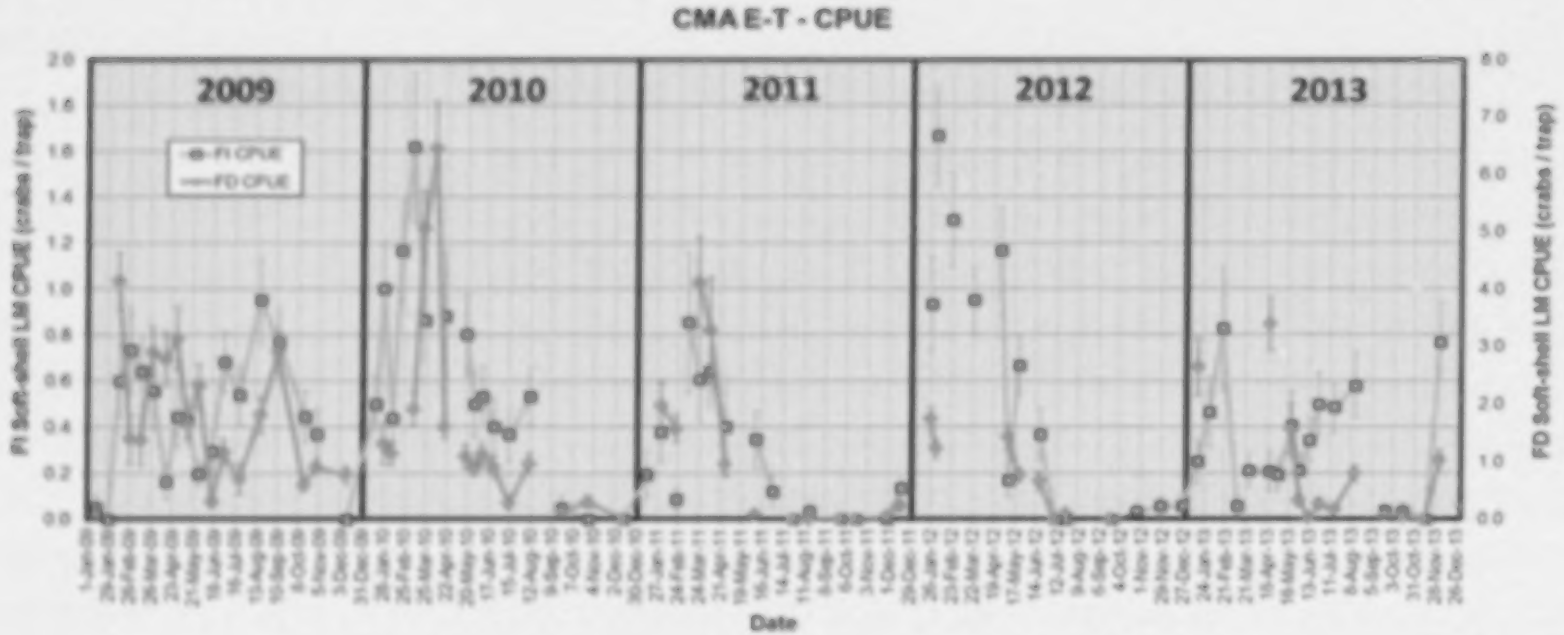


Figure 25. Crab Management Area (CMA) E-T 2009 to 2013 observed CPUE from the (a) fishery-independent (FI, blue markers and lines) and (b) fishery-dependent (FD, red markers and lines) sampling programs of soft-shell legal-sized male (LM) Dungeness Crab per sampling event (± SE). Disconnected lines indicate a scheduled sampling was missed between dates. Note there are separate y-axes for FI and FD CPUE.

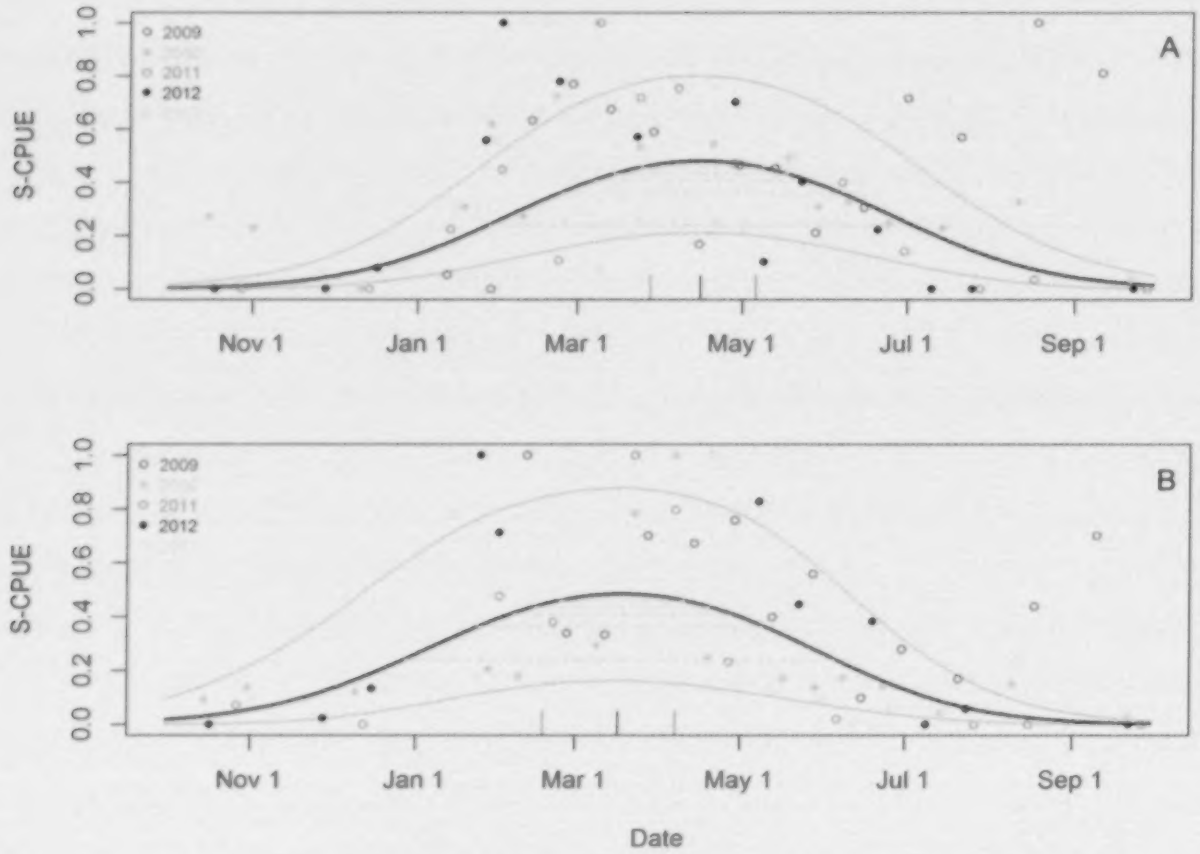
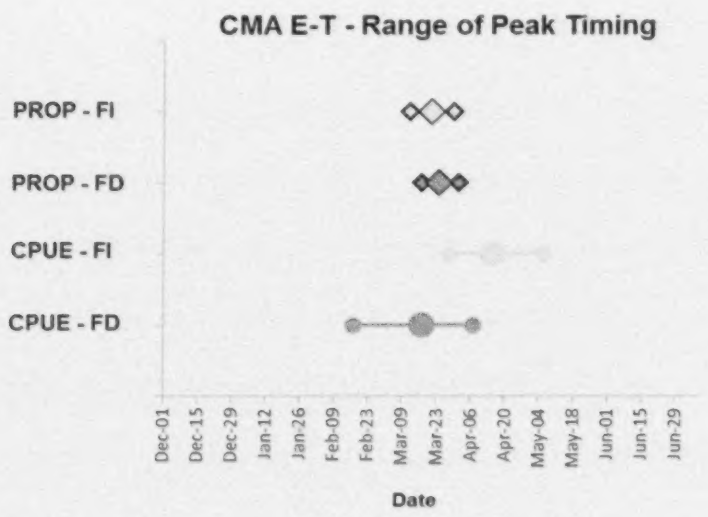


*Figure 26. Crab Management Area E-T 2009 to 2013 CPUE model results using (a) fishery-independent and (b) fishery-dependent data for soft-shell legal-sized male Dungeness Crabs. The predictable variables "days" and "days^2" were significant. See Table 17 and Table 18 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

(a)



(b)

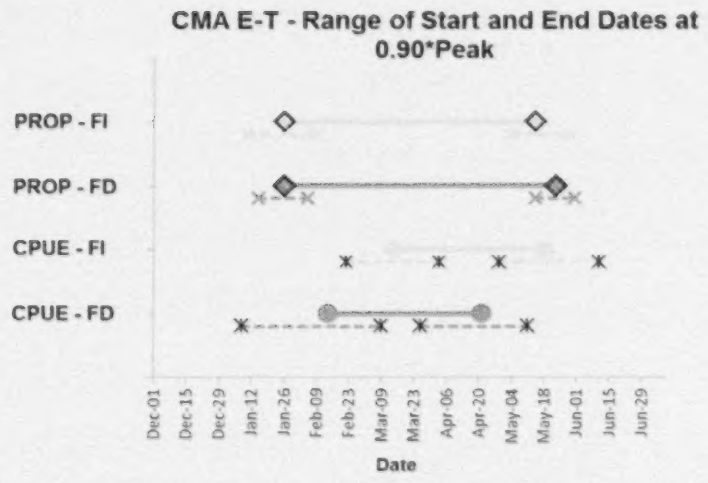


*Figure 27. Crab Management Area (CMA) E-T (2009 to 2013 combined data) comparisons of (a) peak date timing and 95% credible interval (CI) bounds, and (b) start and end date timing and 95% CI at 0.90*Peak for fishery-independent (FI) and fishery-dependent (FD) data using proportion and CPUE analysis methods. (Large symbols represent the peaks while the smaller symbols represent the 95% CI around the peaks; diamonds = proportion model; circles = CPUE model; blue symbols = FI data; red symbols = FD data).*

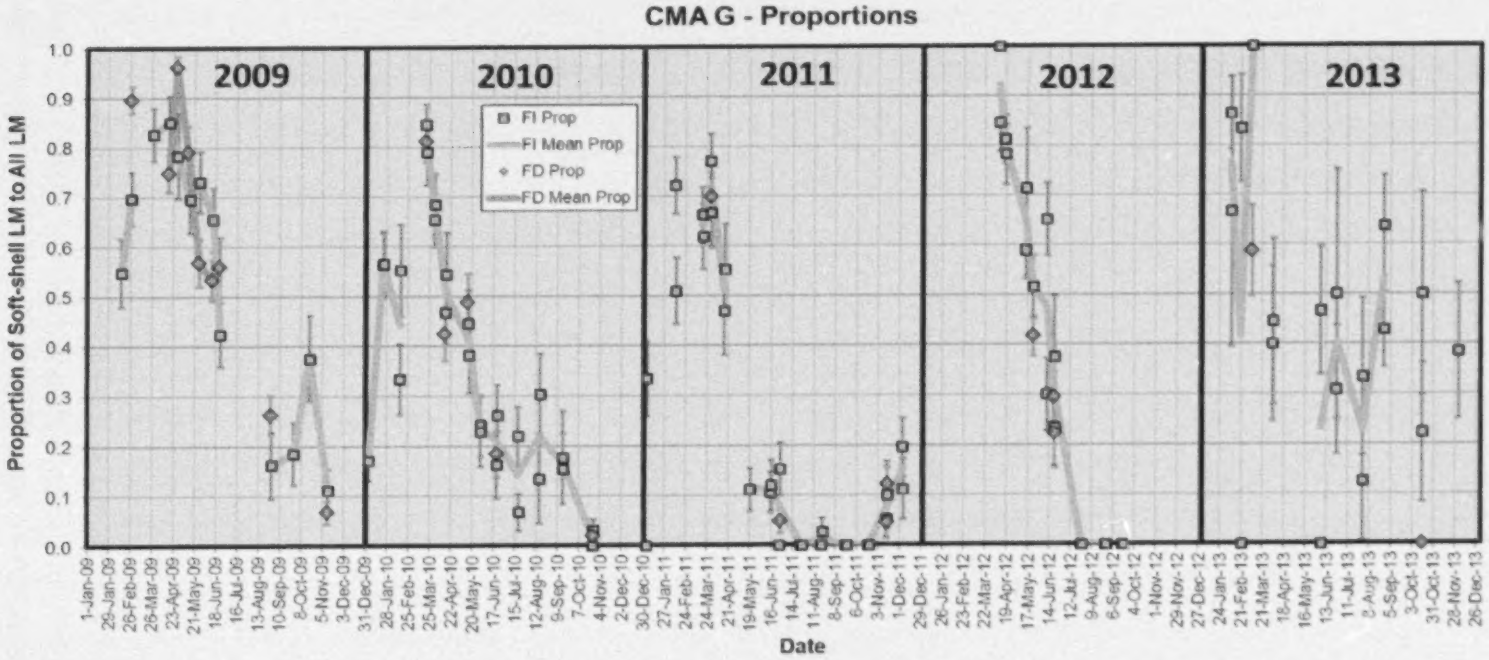


Figure 28. Crab Management Area (CMA) G 2009 to 2013 observed proportions (± SE) from the (a) fishery-independent (FI, blue) and (b) fishery-dependent (FD, red) sampling programs of soft-shell legal-sized male (LM) Dungeness Crabs of all legal-sized males per sampling event (Village Channel and Retreat Passage Index Areas combined). (Blue squares = FI observed data, blue line = mean of FI observed data, red diamonds = FD observed data, red line = mean of FD observed data. Note disconnected lines indicate scheduled sampling was missed between dates).

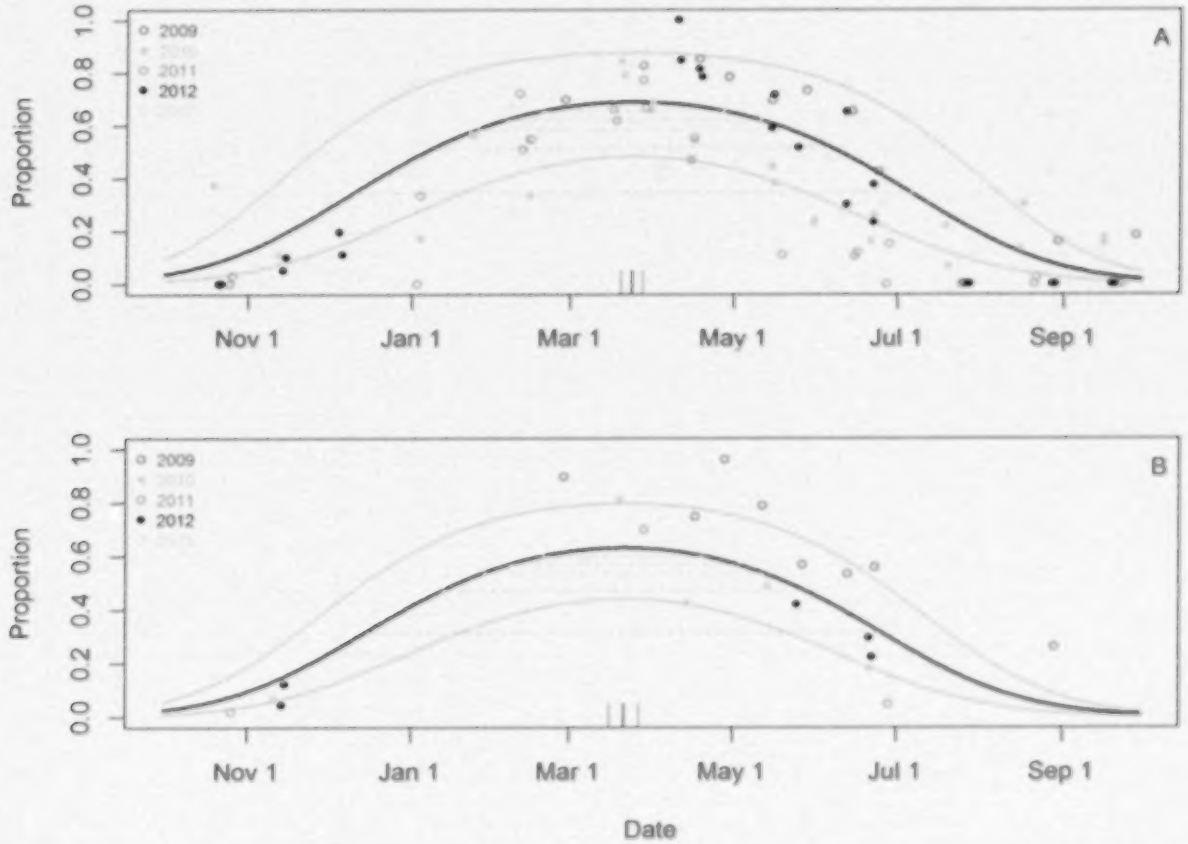


*Figure 29. Crab Management Area G 2009 to 2013 proportion model results using (a) fishery-independent and (b) fishery-dependent data for soft-shell legal-sized male Dungeness Crabs (Village and Retreat Index Areas combined). The predictable variables "days" and "days^2" were significant. See Table 20 and Table 21 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

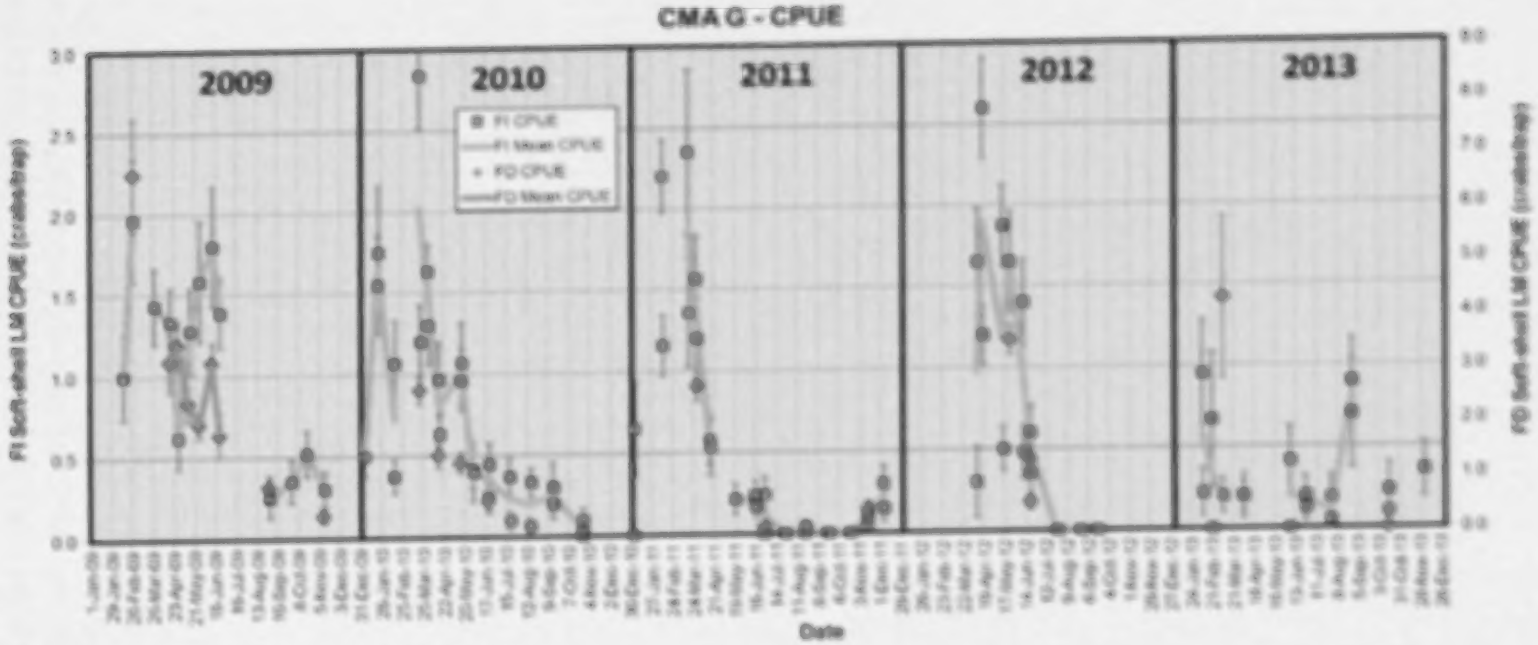


Figure 30. Crab Management Area (CMA) G 2009 to 2013 observed CPUE (± SE) from the (a) fishery-independent (FI, blue) and (b) fishery-dependent (FD, red) sampling programs of soft-shell legal-sized male (LM) Dungeness Crabs per sampling event (Village Channel and Retreat Passage Index Areas combined). (Blue squares = FI observed data, blue line = mean of FI observed data, red diamonds = FD observed data, red line = mean of FD observed data. Note disconnected lines indicate scheduled sampling was missed between dates, and the y-axis has a larger scale on the FD graph than on the FI graph).

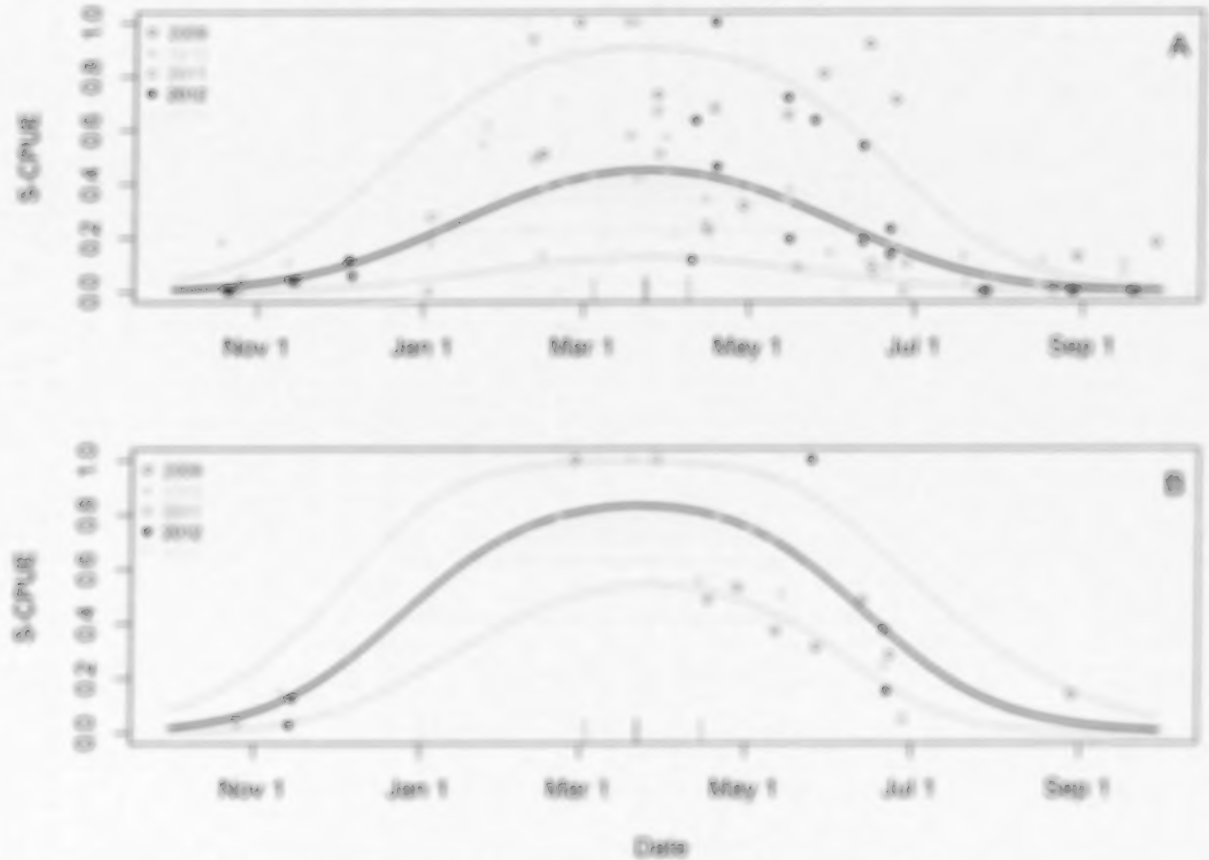
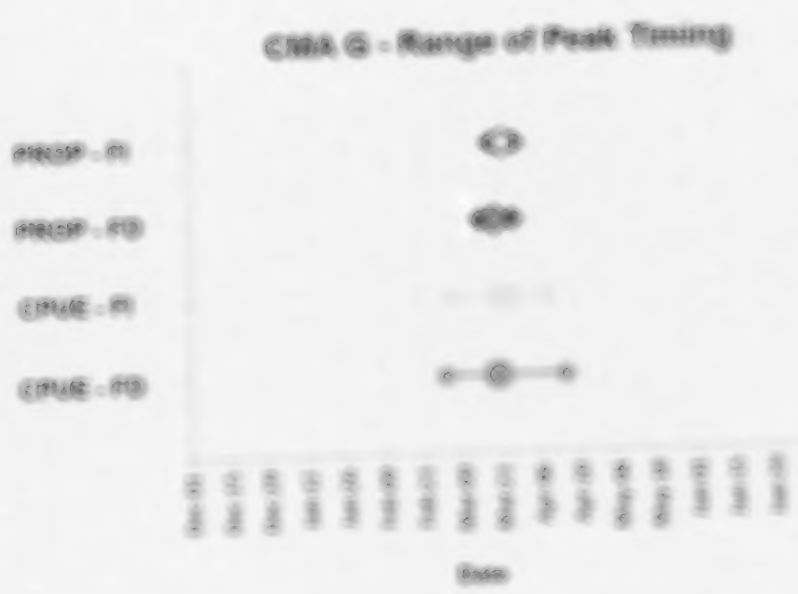


*Figure 31. Crab Management Area G 2009 to 2013 CPUE model results using (a) fishery-independent, and (b) fishery-dependent data for soft-shell legal-sized male Dungeness Crabs (Village and Retreat Index Areas combined). The predictable variables "days" and "days^2" were significant. See Table 22 and Table 23 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion from the top down, 0.95*Peak, 0.90*Peak, 0.80*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

(a)



(b)

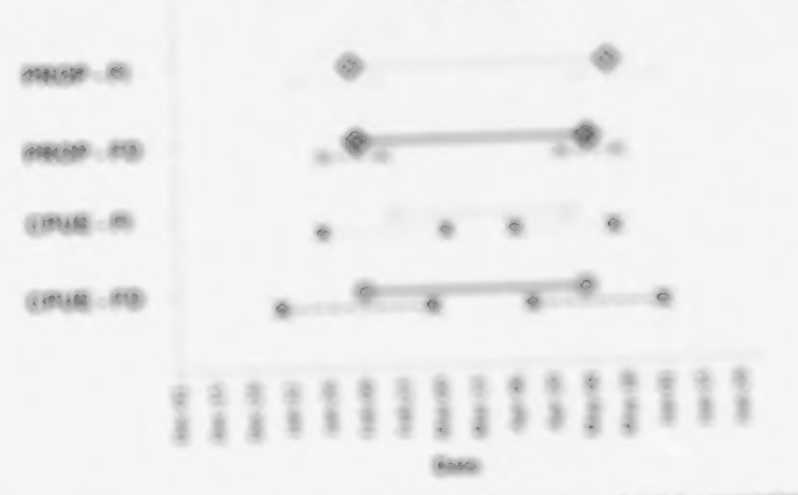


Figure 32. Crab Management Area (CMA) G (2008 to 2013) combined data comparisons of (a) peak date timing and 80% credible interval (CI) bounds, and (b) start and end date timing and 80% CI at 0.80 Peak for fishery-independent (FI) and fishery-dependent (FD) data using proportion and CPUE analysis methods. (Large symbols represent the points while the smaller symbols represent the 80% CI around the points; diamonds = proportion model; circles = CPUE model; blue symbols = FI data; red symbols = FD data)

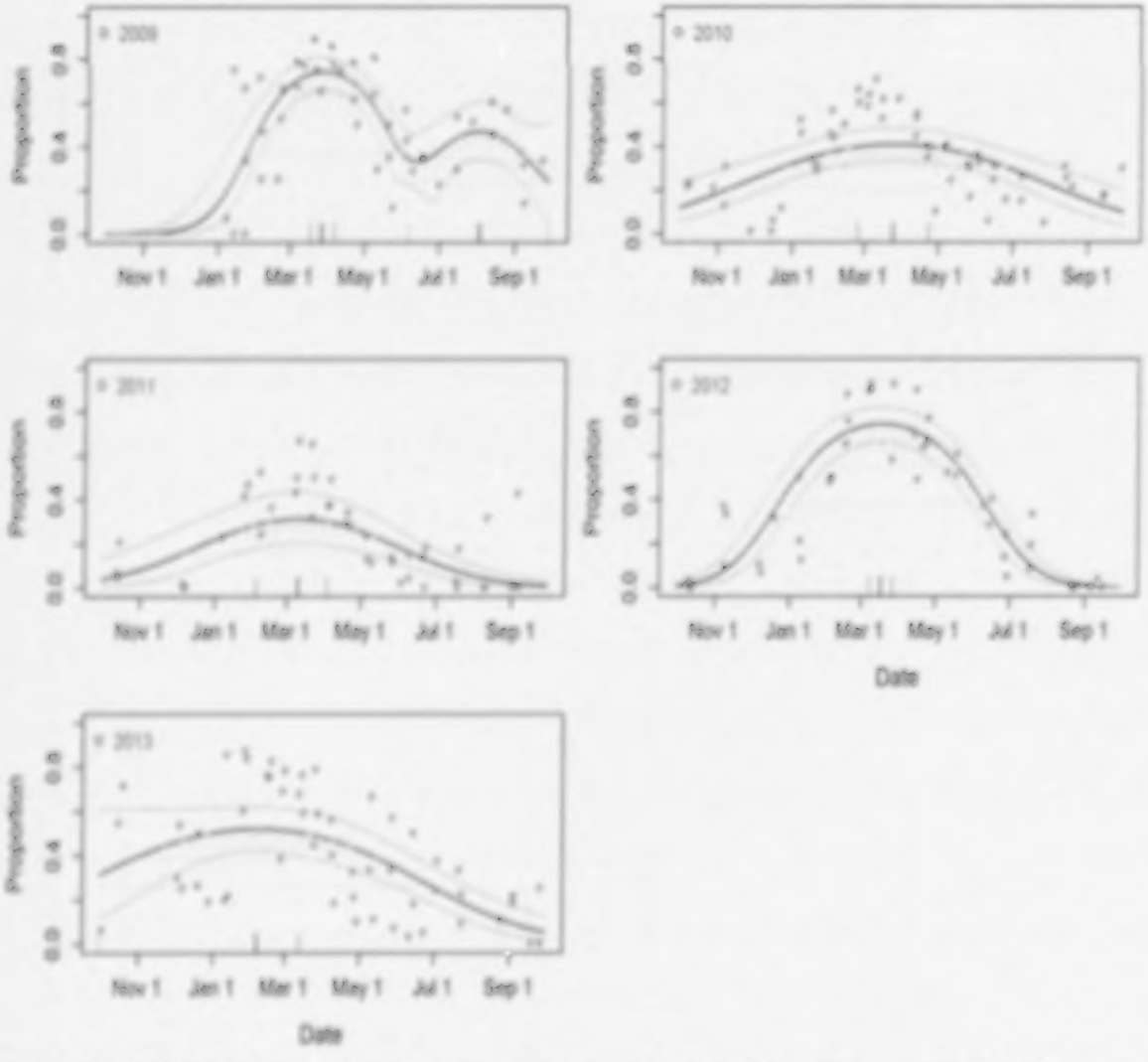


*Figure 33. Crab Management Area H proportion model results using fishery-independent (FI) data for soft-shell legal-sized male Dungeness Crabs (Nanaimo, Ganges and Sidney Index Areas combined) by year. Model fits were significant for all years, each having p(coef. for days>0)≥0.95 and p(coef. for days^2>0)≤0.05. See Table 25 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI)*

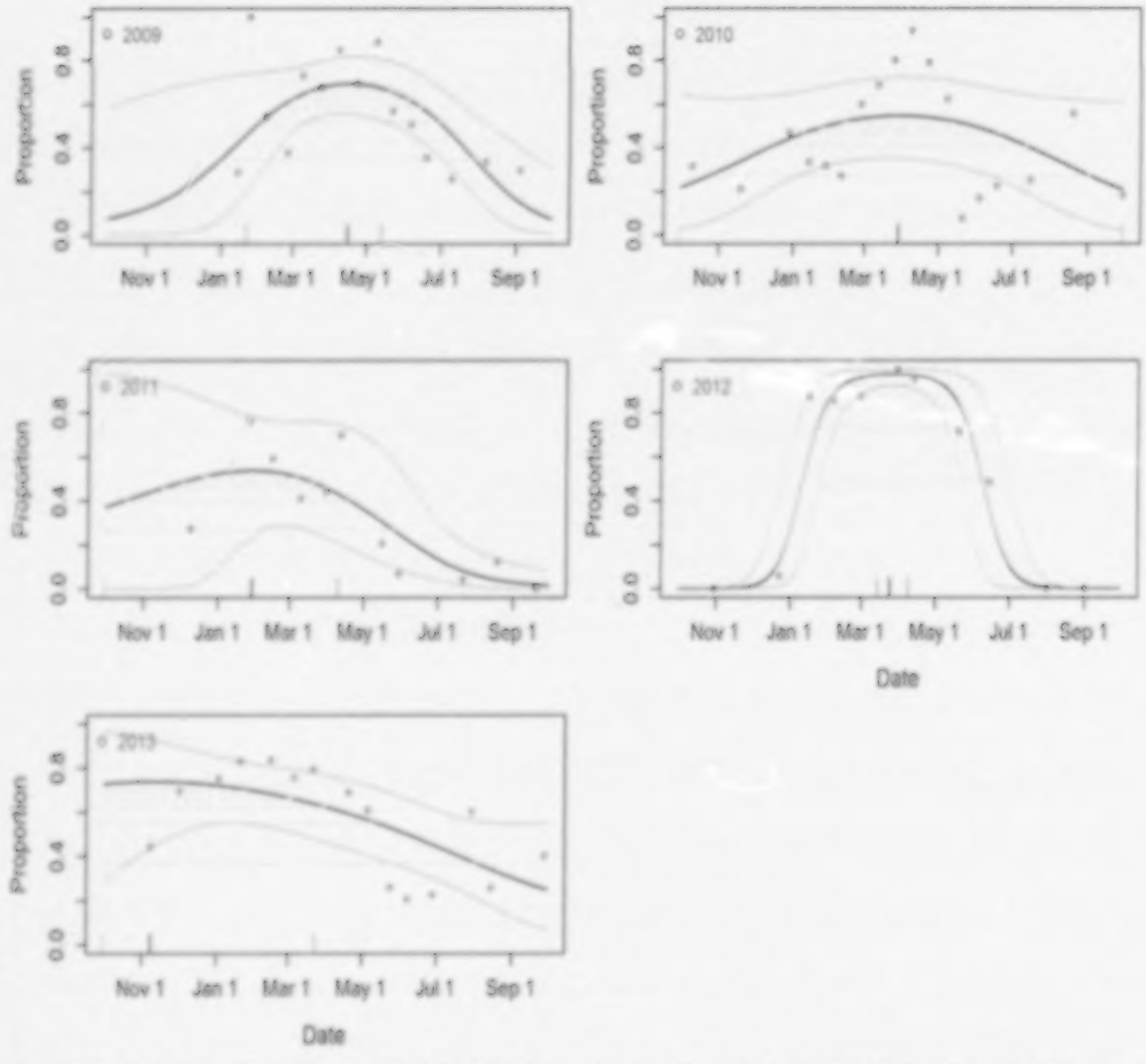


*Figure 34. Crab Management Area E-S proportion model results using fishery-independent (FI) data for soft-shell legal-sized male Dungeness Crabs by year. Note model fits were only significant for years 2009 and 2012, each having p(coef. for days>0)≥0.95 and p(coef. for days^2>0)≤0.05. Results for years 2010, 2011 and 2013 were not significant. See Table 26 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

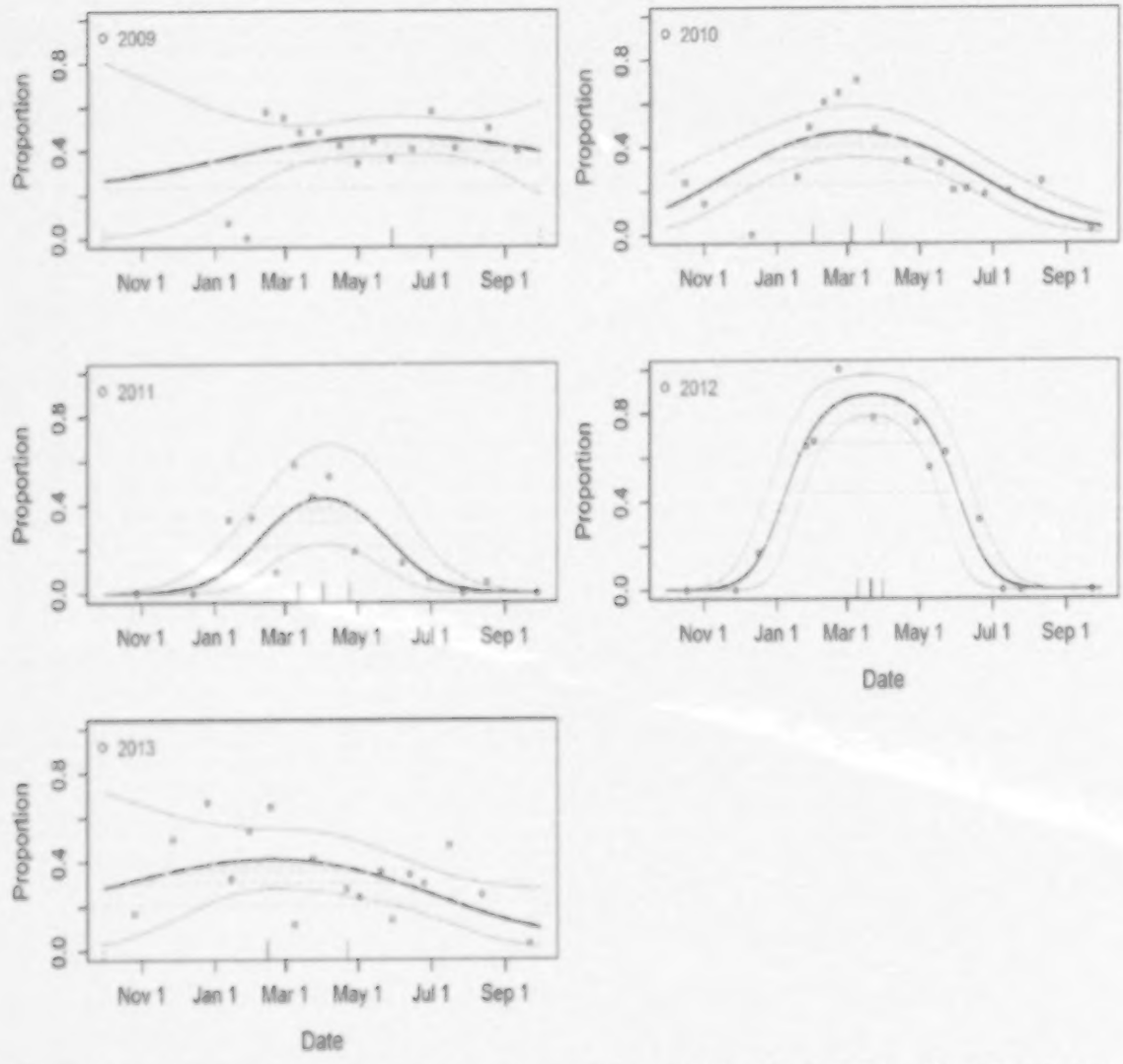


*Figure 35. Crab Management Area E-T proportion model results using fishery-independent (FI) data for soft-shell legal-sized male Dungeness Crabs by year. Model fits were only significant for years 2010 to 2012, each having p(coef. for days>0)≥0.95 and p(coef. for days^2>0)≤0.05. Results were not significant for years 2009 and 2013. See Table 27 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

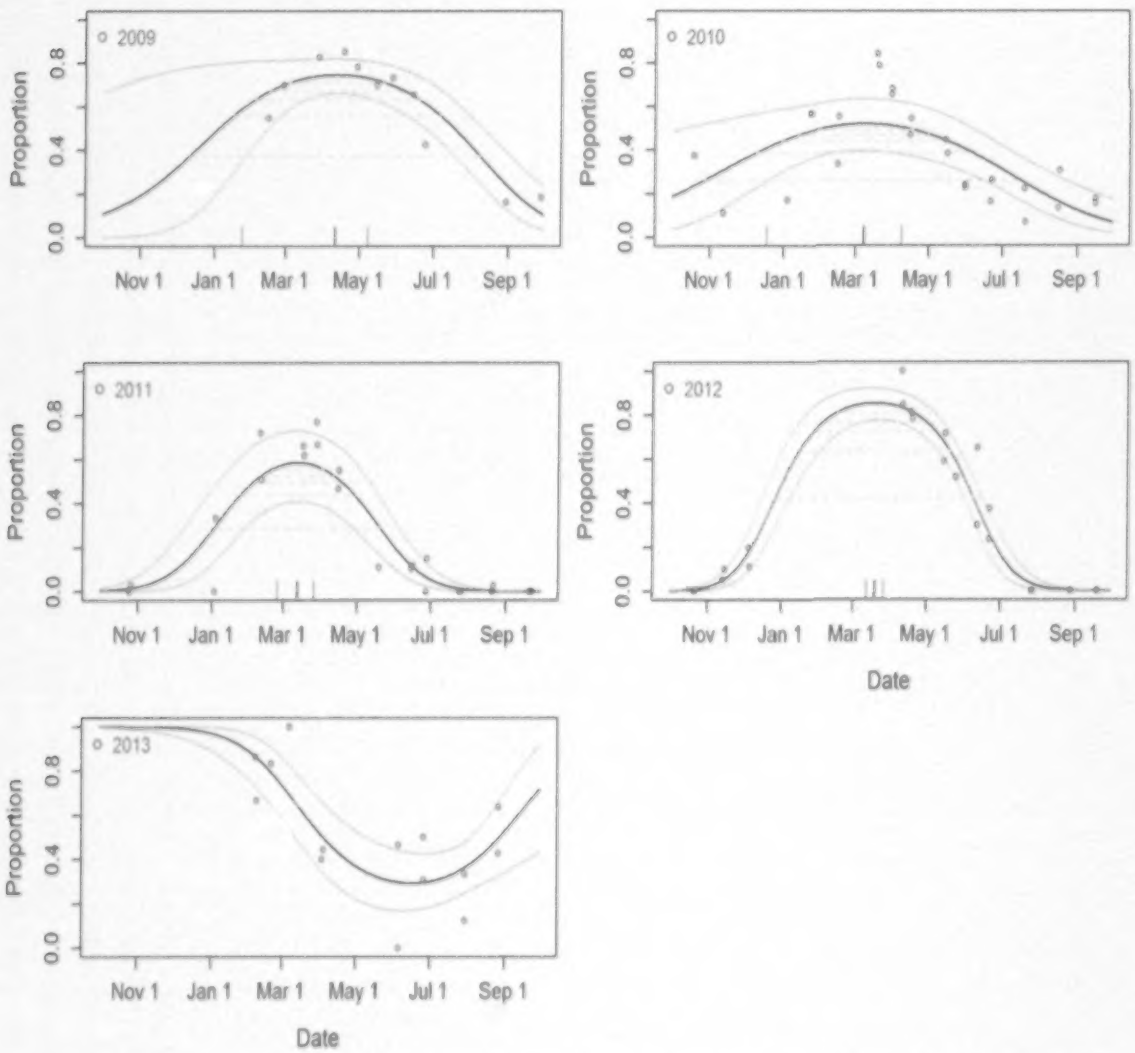


*Figure 36. Crab Management Area G proportion model results using fishery-independent (FI) data for soft-shell legal-sized male Dungeness Crabs (Village Channel and Retreat Passage Index Areas combined) by year. Model fits were significant for years 2009 to 2012, each having p(coef. for days>0)≥0.95 and p(coef. for days^2>0)≤0.05. Results were not significant for year 2013. See Table 28 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

APPENDIX A: OBSERVED DATA AND MODEL RESULTS FOR EACH INDEX AREA (NANAIMO, GANGES, SIDNEY) WITHIN CMA H

*Table A1. Crab Management Area H by index area 2009 to 2013 results of the proportion model using fishery-independent (FI) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure A2). The predictable variables "days" and "days^2" were significant for all index areas. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively; L95% and U95% the lower and upper 95% credible interval (CI) bounds, respectively, for the proportion values; Start Date and End Date estimated start and end dates of the time period when proportions were at, or above, the particular reduction level from the peak proportion; Start to End Length=number of days from the estimated start to end dates; Peak / or Start and End Date Variability=95% CI around the peak date, or around both the start and end dates).*

Index Area	Model Peak & Reductions from Peak	Prop of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
Nanaimo	Peak	0.36	**0.52**	0.70		Mar 15		1	7	0.3525	82
	0.95*Peak	0.34	**0.50**	0.66	Feb 09		Apr 19	70	9		
	0.90*Peak	0.32	**0.47**	0.63	Jan 27		May 03	97	12		
	0.85*Peak	0.31	**0.44**	0.59	Jan 16		May 14	119	13		
	0.75*Peak	0.27	**0.39**	0.52	Dec 29		Jun 01	155	14		
	0.50*Peak	0.18	**0.26**	0.35	Nov 24		Jul 06	225	16		
Ganges	Peak	0.32	**0.56**	0.75		Mar 12		1	10	0.0573	81
	0.95*Peak	0.30	**0.53**	0.72	Jan 28		Apr 26	89	15		
	0.90*Peak	0.29	**0.50**	0.68	Jan 11		May 13	123	17		
	0.85*Peak	0.27	**0.47**	0.64	Dec 28		May 27	151	20		
	0.75*Peak	0.24	**0.42**	0.57	Dec 06		Jun 18	195	22		
	0.50*Peak	0.16	**0.28**	0.38	Oct 24		Jul 31	281	24		
Sidney	Peak	0.37	**0.53**	0.70		Mar 17		1	6	0.5385	79
	0.95*Peak	0.35	**0.51**	0.66	Feb 14		Apr 19	65	8		
	0.90*Peak	0.33	**0.48**	0.63	Feb 01		May 02	91	10		
	0.85*Peak	0.31	**0.45**	0.59	Jan 22		May 12	111	11		
	0.75*Peak	0.28	**0.40**	0.52	Jan 06		May 28	143	12		
	0.50*Peak	0.18	**0.27**	0.35	Dec 05		Jun 29	207	14		

*Table A2. Crab Management Area H by index area 2009 to 2013 results of the proportion model using fishery-dependent (FD) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure A3). The predictable variables "days" and "days^2" were significant for all index areas. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively; L95% and U95% the lower and upper 95% credible interval (CI) bounds, respectively, for the proportion values; Start Date and End Date estimated start and end dates of the time period when proportions were at, or above, the particular reduction level from the peak proportion; Start to End Length=number of days from the estimated start to end dates; Peak / or Start and End Date Variability=95% CI around the peak date, or around both the start and end dates).*

Index Area	Model Peak & Reductions from Peak	Prop of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
Nanaimo	Peak	0.29	0.50	0.74		Mar 01		1	14	0.4659	51
	0.95*Peak	0.28	0.48	0.71	Jan 16		Apr 16	91	19		
	0.90*Peak	0.26	0.45	0.67	Dec 29		May 04	127	21		
	0.85*Peak	0.25	0.43	0.63	Dec 15		May 18	155	23		
	0.75*Peak	0.22	0.38	0.56	Nov 22		Jun 10	201	26		
	0.50*Peak	0.15	0.25	0.37	Oct 07		Jul 26	293	N/A		
Ganges	Peak	0.39	0.46	0.55		Mar 09		1	10	0.3172	51
	0.95*Peak	0.37	0.44	0.52	Jan 24		Apr 25	92	11		
	0.90*Peak	0.35	0.42	0.49	Jan 05		May 14	130	12		
	0.85*Peak	0.33	0.39	0.46	Dec 22		May 28	158	13		
	0.75*Peak	0.29	0.35	0.41	Nov 28		Jun 21	206	14		
	0.50*Peak	0.19	0.23	0.27	Oct 10		Aug 09	304	14		
Sidney	Peak	0.39	0.56	0.73		Mar 04		1	8	0.5859	62
	0.95*Peak	0.37	0.53	0.70	Jan 24		Apr 13	80	11		
	0.90*Peak	0.35	0.50	0.66	Jan 09		Apr 29	111	13		
	0.85*Peak	0.33	0.47	0.62	Dec 27		May 11	136	14		
	0.75*Peak	0.29	0.42	0.55	Dec 08		May 31	175	16		
	0.50*Peak	0.19	0.28	0.37	Oct 30		Jul 09	253	18		

*Table A3. Crab Management Area H by index area 2009 to 2013 results of the CPUE model using fishery-independent (FI) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure A5). The predictable variables "days" and "days^2" were significant for all index areas. (Peak= maximum relative abundance and date of maximum relative abundance; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak relative abundance, or 95%, 90%, 85%, 75% and 50% of the peak relative abundance, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the relative abundance values; Start Date and End Date = estimated start and end dates of the time period when the relative abundances were at, or above, the particular reduction level from the peak relative abundance; Start to End Length = number of days from the estimated start to end dates (note this value does not change); Peak / or Start and End Date Variability = 95% CI bounds around the peak date, or around both the start and end dates).*

Index Area	Model Peak & Reductions from Peak	S-CPUE of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
Nanaimo	Peak	0.20	**0.35**	0.57		Mar 12		1	28	0.1447	82
	0.95*Peak	0.19	**0.34**	0.54	Feb 16		Apr 09	53	29		
	0.90*Peak	0.18	**0.32**	0.51	Feb 06		Apr 19	73	29		
	0.85*Peak	0.17	**0.30**	0.48	Jan 28		Apr 28	91	29		
	0.75*Peak	0.15	**0.27**	0.42	Jan 14		May 12	119	30		
	0.50*Peak	0.10	**0.18**	0.28	Dec 13		Jun 11	181	33		
Ganges	Peak	0.22	**0.49**	0.81		Apr 17		1	31	0.0573	81
	0.95*Peak	0.21	**0.47**	0.77	Mar 17		May 17	62	32		
	0.90*Peak	0.20	**0.44**	0.73	Mar 05		May 29	86	33		
	0.85*Peak	0.19	**0.42**	0.69	Feb 23		Jun 08	106	34		
	0.75*Peak	0.17	**0.37**	0.61	Feb 07		Jun 25	139	36		
	0.50*Peak	0.11	**0.25**	0.41	Jan 04		Jul 30	208	40		
Sidney	Peak	0.18	**0.52**	0.92		Mar 25		1	19	0.2723	79
	0.95*Peak	0.18	**0.49**	0.88	Mar 03		Apr 20	49	21		
	0.90*Peak	0.17	**0.47**	0.83	Feb 21		Apr 30	69	22		
	0.85*Peak	0.16	**0.44**	0.79	Feb 13		May 08	85	23		
	0.75*Peak	0.14	**0.39**	0.69	Jan 31		May 20	110	24		
	0.50*Peak	0.09	**0.26**	0.46	Jan 04		Jun 16	164	25		

*Table A4. Crab Management Area H by index area 2009 to 2013 results of the CPUE model using fishery-dependent (FD) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure A6). The predictable variables "days" and "days^{2}" were significant for all index areas except for "days" for Nanaimo. (Peak= maximum relative abundance and date of maximum relative abundance; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak relative abundance, or 95%, 90%, 85%, 75% and 50% of the peak relative abundance, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the relative abundance values; Start Date and End Date = estimated start and end dates of the time period when the relative abundances were at, or above, the particular reduction level from the peak relative abundance; Start to End Length = number of days from the estimated start to end dates (note this value does not change); Peak / or Start and End Date Variability = 95% CI bounds around the peak date, or around both the start and end dates).*

Index Area	Model Peak & Reductions from Peak	S-CPUE of Soft LM			Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
		L95%		U95%							
Nanaimo	Peak	0.20	0.96	0.98		Feb 19		1	N/A	0.3821	51
	0.95*Peak	0.19	0.54	0.93	Jan 31		Apr 13	73	N/A		
	0.90*Peak	0.18	0.51	0.89	Jan 16		Apr 27	102	N/A		
	0.85*Peak	0.17	0.48	0.84	Jan 03		May 09	127	N/A		
	0.75*Peak	0.15	0.42	0.74	Dec 13		May 27	166	N/A		
	0.50*Peak	0.10	0.26	0.49	Oct 21		Jul 05	256	N/A		
Ganges	Peak	0.23	0.56	0.90		Mar 17		1	34	0.2541	51
	0.95*Peak	0.22	0.53	0.86	Feb 19		Apr 19	60	36		
	0.90*Peak	0.21	0.51	0.81	Feb 07		Apr 30	83	37		
	0.85*Peak	0.19	0.48	0.77	Jan 28		May 10	103	38		
	0.75*Peak	0.17	0.42	0.68	Jan 13		May 25	133	40		
	0.50*Peak	0.11	0.28	0.45	Dec 11		Jun 28	198	43		
Sidney	Peak	0.16	0.53	0.94		Mar 14		1	31	0.2818	62
	0.95*Peak	0.16	0.50	0.89	Feb 18		Apr 12	54	34		
	0.90*Peak	0.15	0.47	0.85	Feb 07		Apr 23	76	35		
	0.85*Peak	0.14	0.45	0.80	Jan 29		May 01	93	35		
	0.75*Peak	0.12	0.39	0.71	Jan 15		May 15	121	36		
	0.50*Peak	0.08	0.26	0.47	Dec 15		Jun 13	181	38		

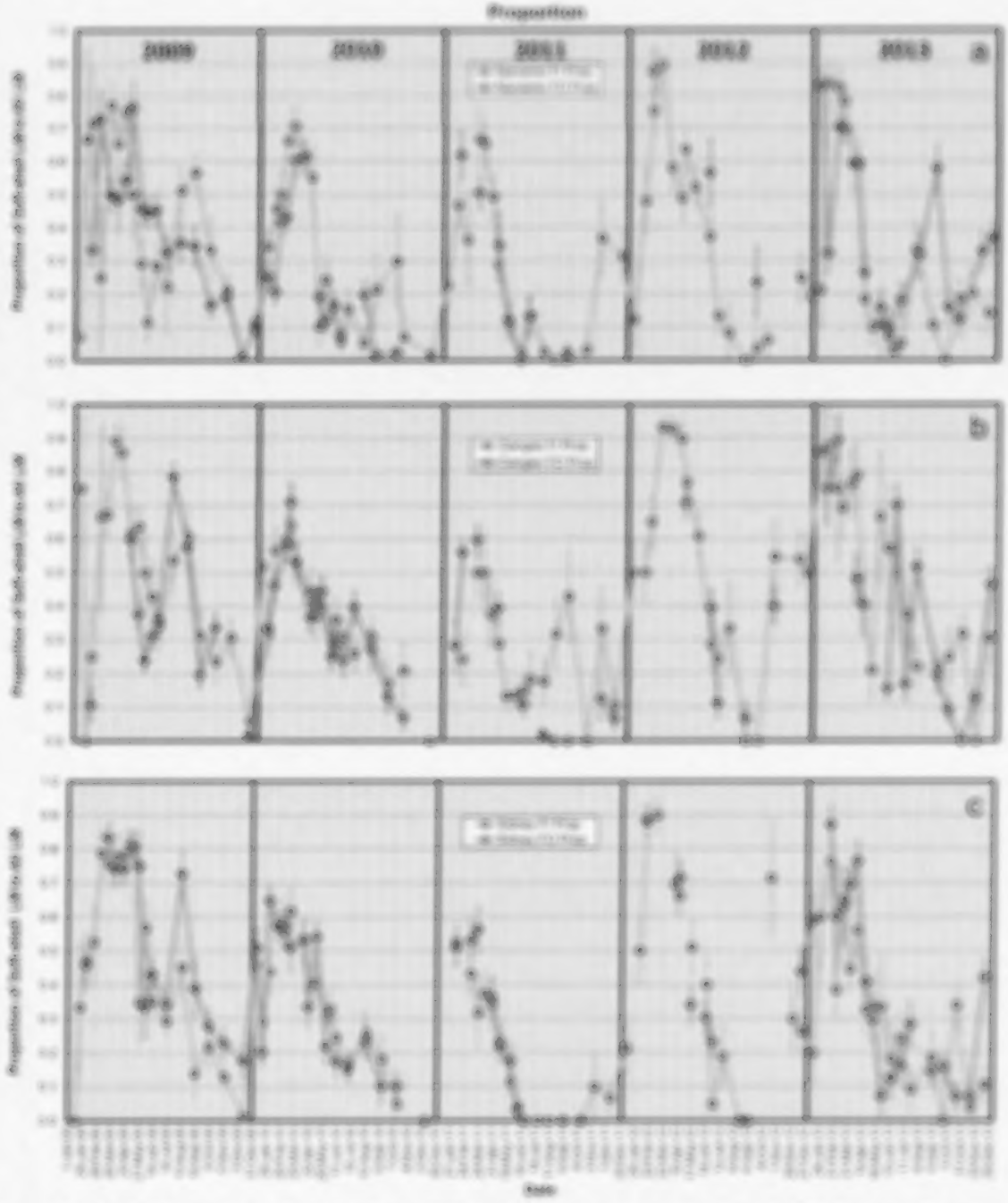


Figure A1. Crab Management Area (CMA) in 2009 to 2013 observed proportions (± SE) from the fishery-independent (FI, blue) and fishery-dependent (FD, red) sampling programs in index areas (a) Tasmania, (b) Ganges, and (c) Sidney of soft-shell legal-sized male (LM) Dungeness Crabs of all legal-sized males per sampling event. Disconnected lines indicate scheduled sampling was missed between dates.

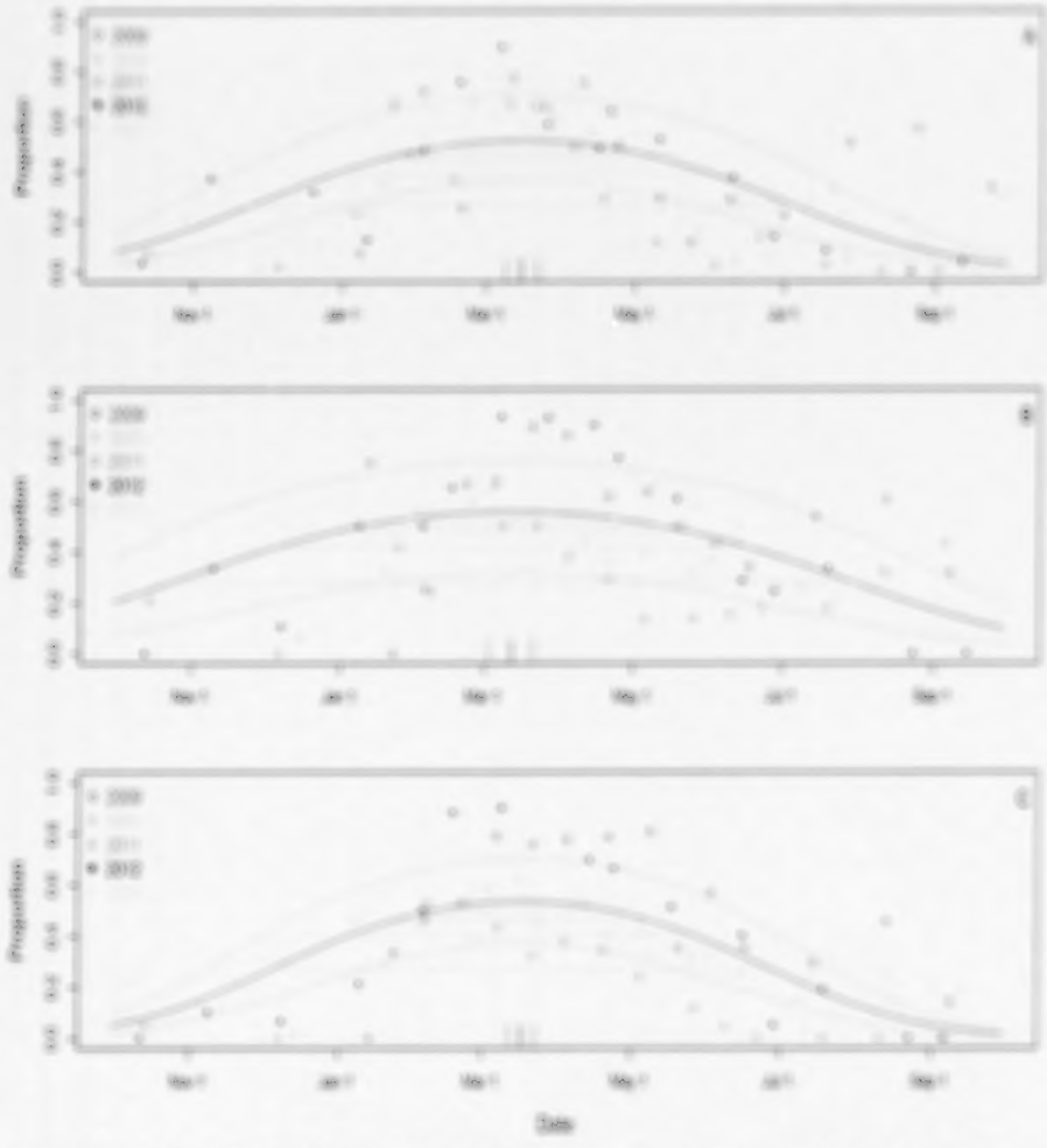


Figure A2. Crab Management Area (4) 2009 to 2013 proportion model results using fishery independent (FI) data in index areas (a) Nanaimo, (b) Georgia, and (c) Sidney for soft-shell legal-sized male Dungeness Crabs. The predictable variables 'days' and 'days^2' were significant. See Table A1 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion from the top down, 0.95thPeak, 0.90thPeak, 0.85thPeak, 0.75thPeak and 0.50thPeak, respectively red and black vertical lines above x-axis = peak date and 95% CI).

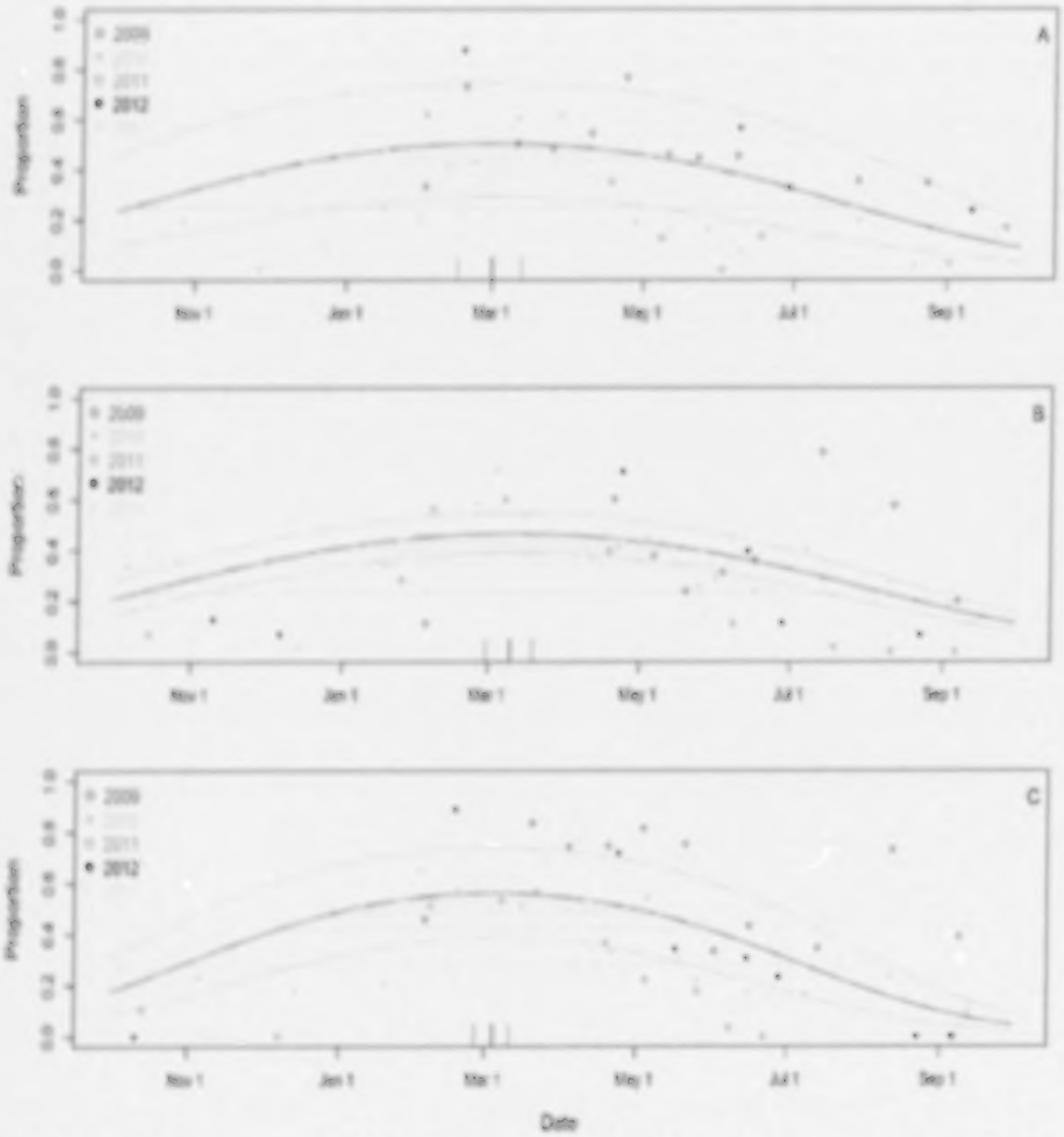


*Figure A3. Crab Management Area H 2009 to 2013 proportion model results using fishery-dependent (FD) data in index areas (a) Nanaimo, (b) Gangers, and (c) Sidney for soft-shell legal-sized male Dungeness Crabs. The predictable variables "days" and "days^{2}" were significant. See Table A2 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

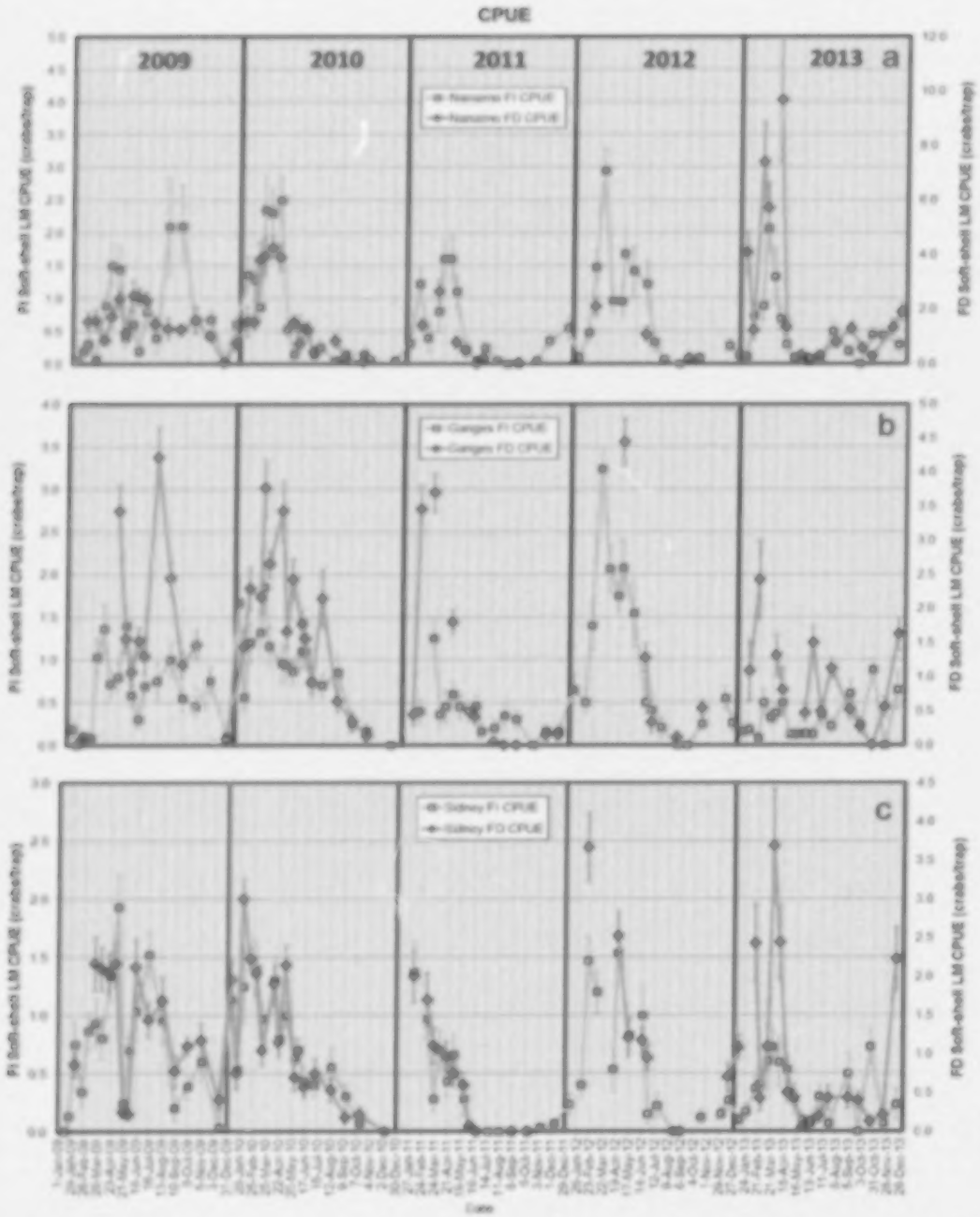


Figure A4. Crab Management Area (CMA) H 2009 to 2013 observed CPUE (± SE) from the fishery-independent (FI, blue) and fishery-dependent (FD, red) sampling programs in index areas (a) Nanaimo, (b) Ganges, and (c) Sidney of soft-shell legal-sized male (LM) Dungeness Crab. Disconnected lines indicate scheduled sampling was missed between dates. Note varying scales on the y-axis.

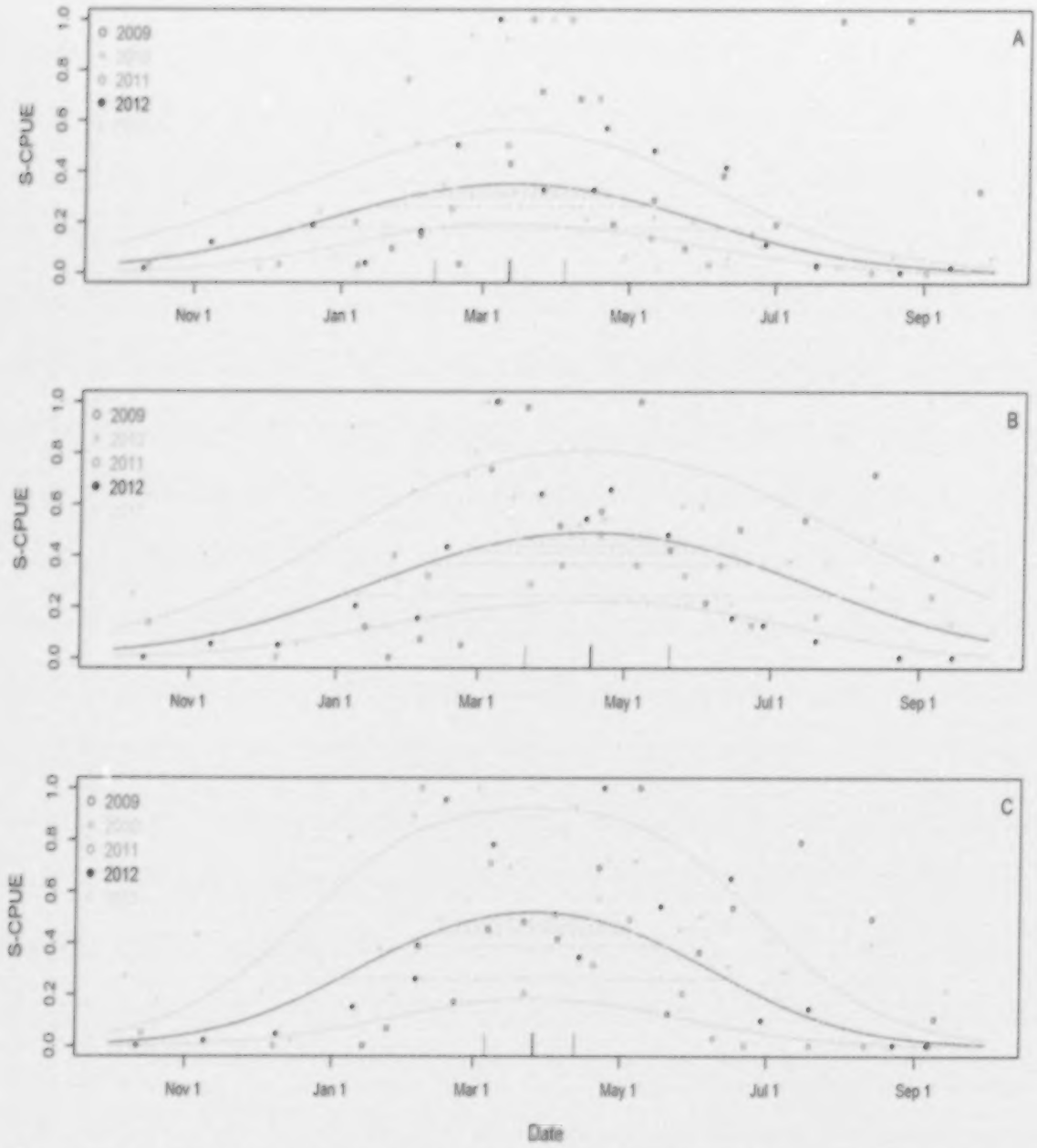


*Figure A5. Crab Management Area H 2009 to 2013 CPUE model results using fishery-independent (FI) data in index areas (a) Nanaimo, (b) Ganges, and (c) Sidney for soft-shell legal-sized male Dungeness Crabs. The predictable variables "days" and "days^2" were significant. See Table A3 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

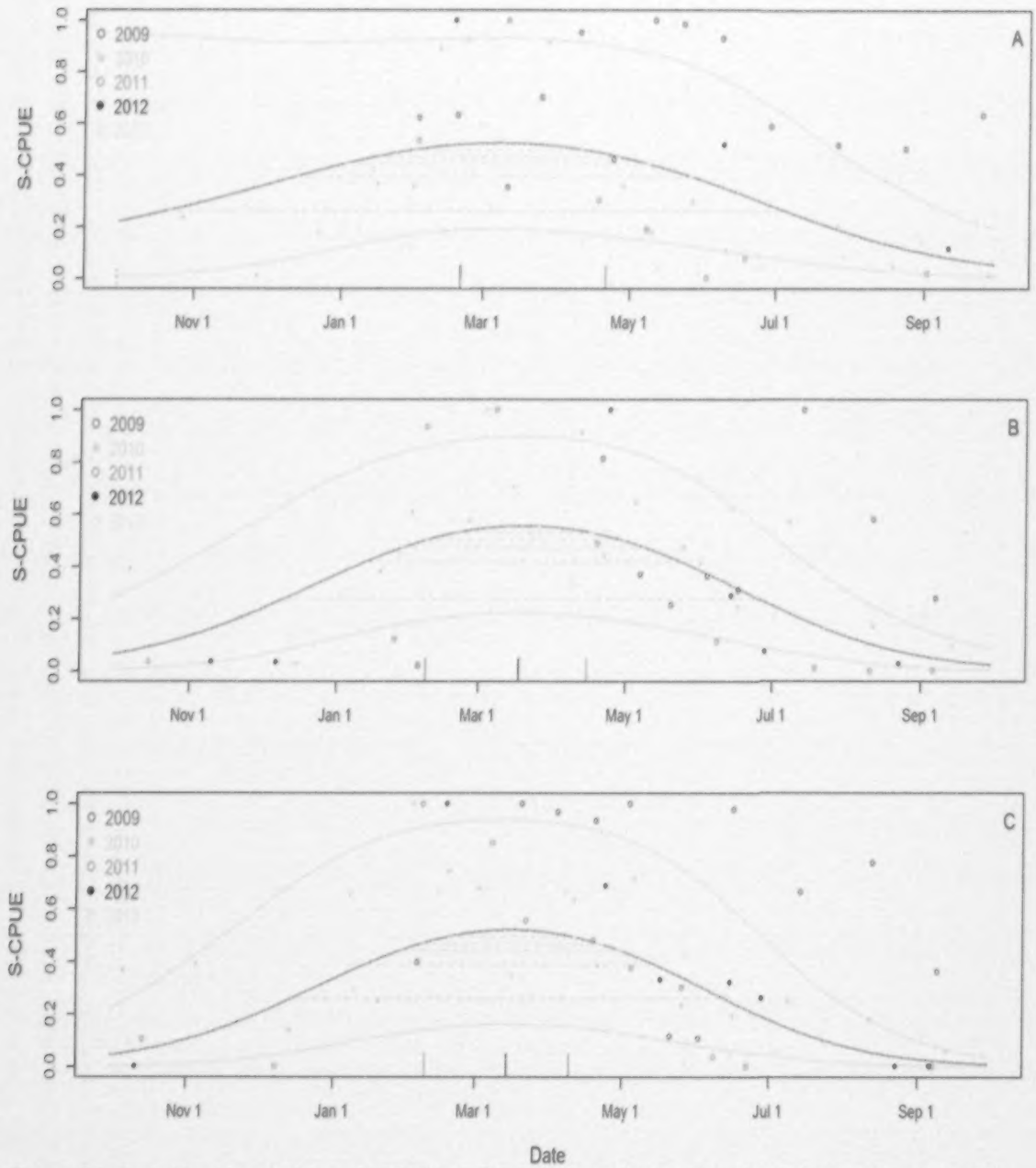


*Figure A6. Crab Management Area H 2009 to 2013 CPUE model results using fishery-dependent (FD) data in index areas (a) Nanaimo, (b) Ganges, and (c) Sidney for soft-shell legal-sized male Dungeness Crabs. The predictable variables "days" and "days^2" were significant, except for "days" for Nanaimo. See Table A4 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

APPENDIX B: OBSERVED DATA AND MODEL RESULTS FOR EACH INDEX AREA (VILLAGE CHANNEL AND RETREAT PASSAGE) WITHIN CMA G

*Table B1. Crab Management Area G by index area 2009 to 2013 results of the proportion model using fishery-independent (FI) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure B2). The predictable variables "days" and "days^2" were significant for both index areas. (Peak= maximum proportion and date of maximum proportion; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak proportion, or 95%, 90%, 85%, 75% and 50% of the peak proportion, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the proportion values; Start and End Date = start and end dates of the time period when proportions were always at, or above, the particular reduction level from the peak proportion; Start to End Length = number of days from the start to end dates (soft-shell period); Peak / or Start and End Date Variability = 95% CI around the peak date, or around both the start and end dates).*

Index Area	Model Peak & Reductions from Peak	Prop of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
Village Channel	**Peak**	0.48	**0.68**	0.84		**Mar 21**		**1**	**6**	0.7297	57
	0.95*Peak	0.45	**0.64**	0.80	**Feb 15**		**Apr 26**	71	**12**		
	0.90*Peak	0.43	**0.61**	0.76	**Feb 01**		**May 10**	99	**14**		
	0.85*Peak	0.40	**0.57**	0.72	**Jan 22**		**May 20**	119	**16**		
	0.75*Peak	0.36	**0.51**	0.63	**Jan 06**		**Jun 05**	151	**17**		
	0.50*Peak	0.24	**0.34**	0.42	**Dec 06**		**Jul 06**	213	**18**		
Retreat Passage	**Peak**	0.42	**0.69**	0.90		**Mar 31**		**1**	**7**	0.5033	40
	0.95*Peak	0.40	**0.65**	0.86	**Mar 01**		**May 03**	64	**16**		
	0.90*Peak	0.38	**0.62**	0.81	**Feb 17**		**May 15**	88	**19**		
	0.85*Peak	0.36	**0.59**	0.77	**Feb 07**		**May 24**	107	**21**		
	0.75*Peak	0.31	**0.52**	0.68	**Jan 24**		**Jun 08**	136	**22**		
	0.50*Peak	0.21	**0.34**	0.45	**Dec 28**		**Jul 05**	190	**23**		

*Table B2. Crab Management Area G by index area 2009 to 2013 results of the CPUE model using fishery-independent (FI) data for soft-shell legal-sized male (LM) Dungeness Crabs (see Figure B4). The predictable variables "days" and "days^2" were significant for both index areas. (Peak= maximum relative abundance and date of maximum relative abundance; 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak = reductions from the peak relative abundance, or 95%, 90%, 85%, 75% and 50% of the peak relative abundance, respectively; L95% and U95% = the lower and upper 95% credible interval (CI) bounds, respectively, for the relative abundance values; Start and End Date = start and end dates of the time period when relative abundances were always at, or above, the particular reduction level from the peak relative abundance; Start to End Length = number of days from the start to end dates (soft-shell period); Peak / or Start and End Date Variability = 95% CI around the peak date, or around both the start and end dates).*

Index Area	Model Peak & Reductions from Peak	S-CPUE of Soft LM L95%		U95%	Start Date	Peak Date	End Date	Start to End Length (Days)	Peak / or Start and End Date Variability (Days)	R^2	Sample Events
Village	Peak	0.25	**0.64**	0.98		**Mar 15**		**1**	**22**	0.3078	57
Channel	**0.95*Peak**	0.24	**0.61**	0.93	**Feb 19**		**Apr 11**	52	**26**		
	0.90*Peak	0.22	**0.58**	0.88	**Feb 09**		**Apr 22**	73	**28**		
	0.85*Peak	0.21	**0.55**	0.83	**Feb 01**		**Apr 30**	89	**28**		
	0.75*Peak	0.19	**0.48**	0.73	**Jan 19**		**May 13**	115	**29**		
	0.50*Peak	0.12	**0.32**	0.49	**Dec 23**		**Jun 08**	168	**30**		
Retreat	Peak	0.09	**0.38**	0.87		**Apr 07**		**1**	**33**	0.1223	40
Passage	**0.95*Peak**	0.08	**0.36**	0.83	**Mar 19**		**Apr 29**	42	**35**		
	0.90*Peak	0.08	**0.35**	0.78	**Mar 11**		**May 08**	59	**35**		
	0.85*Peak	0.08	**0.33**	0.74	**Mar 04**		**May 14**	72	**36**		
	0.75*Peak	0.07	**0.29**	0.65	**Feb 21**		**May 25**	94	**36**		
	0.50*Peak	0.04	**0.19**	0.44	**Jan 27**		**Jun 18**	143	**38**		

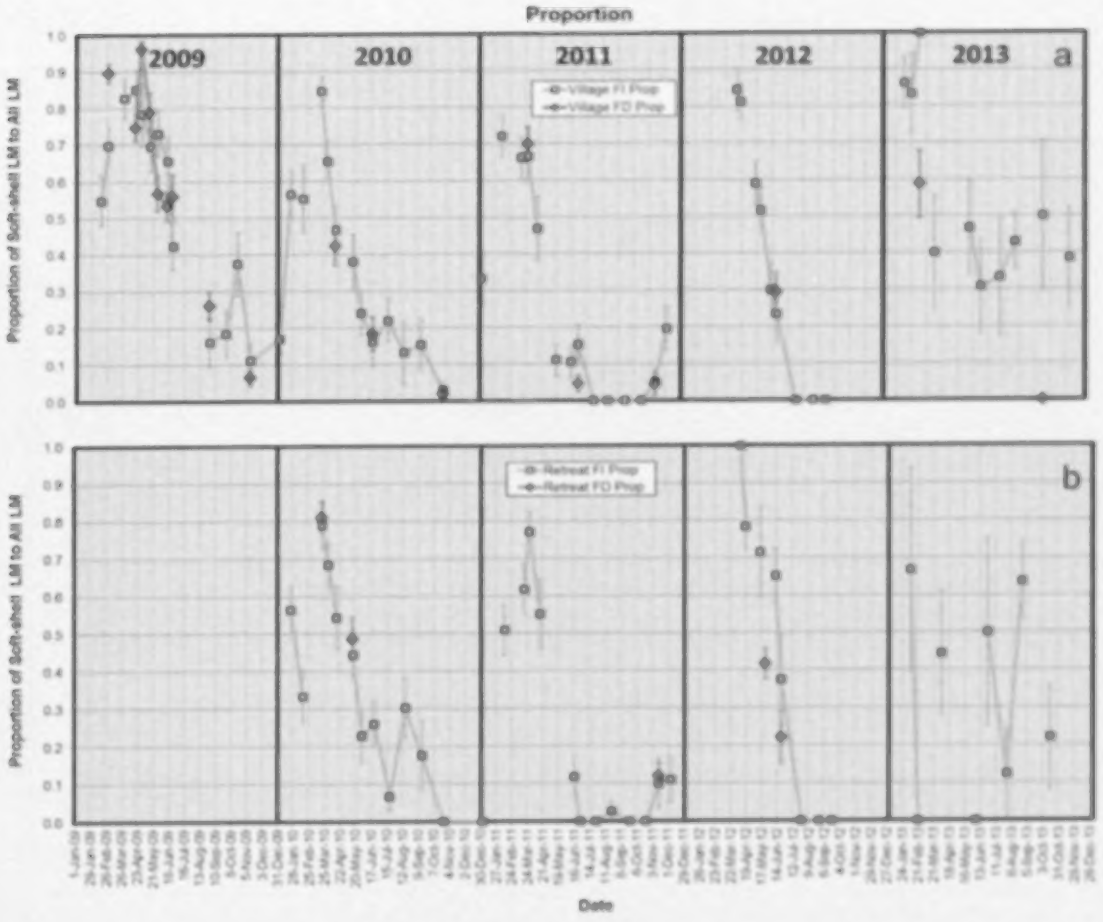


Figure B1. Crab Management Area (CMA) G 2009 to 2013 observed proportions (± SE) from the fishery-independent (FI, blue) and fishery-dependent (FD, red) sampling programs in index areas (a) Village Channel and (b) Retreat Passage of soft-shell legal-sized male (LM) Dungeness Crabs of all legal-sized males per sampling event. Note the sampling programs (FI and FD) did not start in Retreat Passage Index Area until 2010. Disconnected lines indicate scheduled sampling was missed between dates.

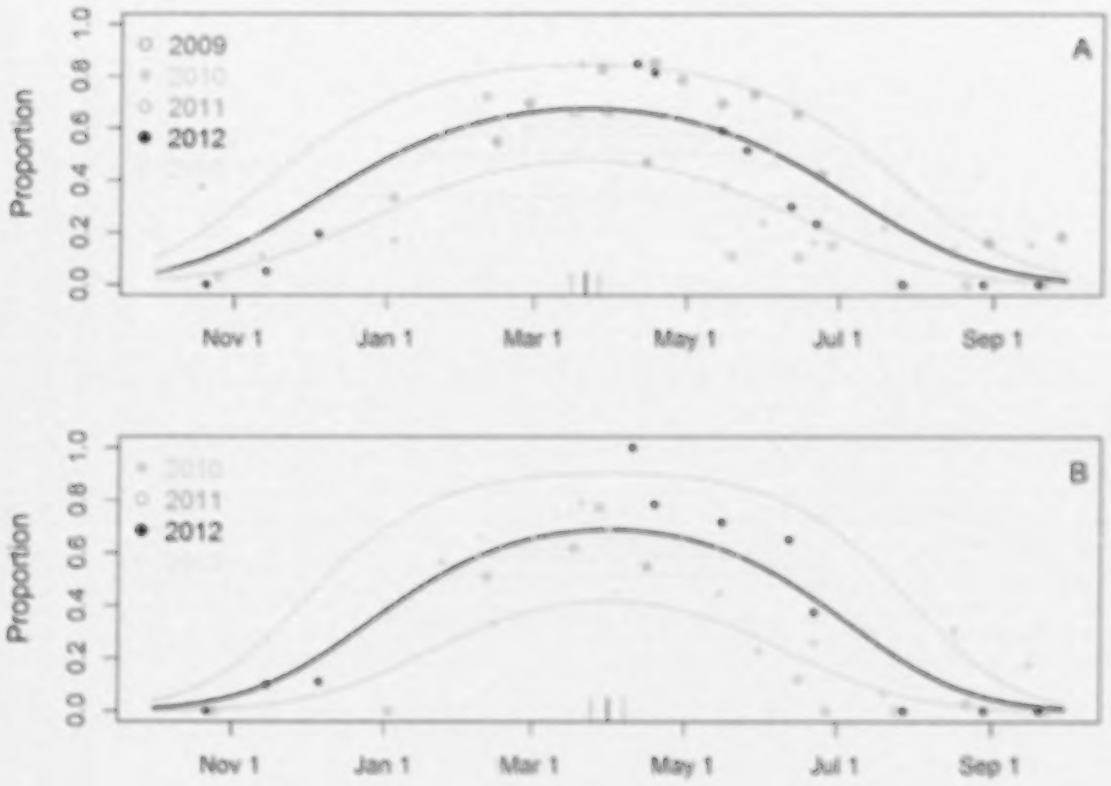


*Figure B2. Crab Management Area G 2009 to 2013 proportion model results using fishery-independent (FI) data in index areas (a) Village Channel and (b) Retreat Passage for soft-shell legal-sized male Dungeness Crabs. The predictable variables "days" and "days^2" were significant. See Table B1 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI).*

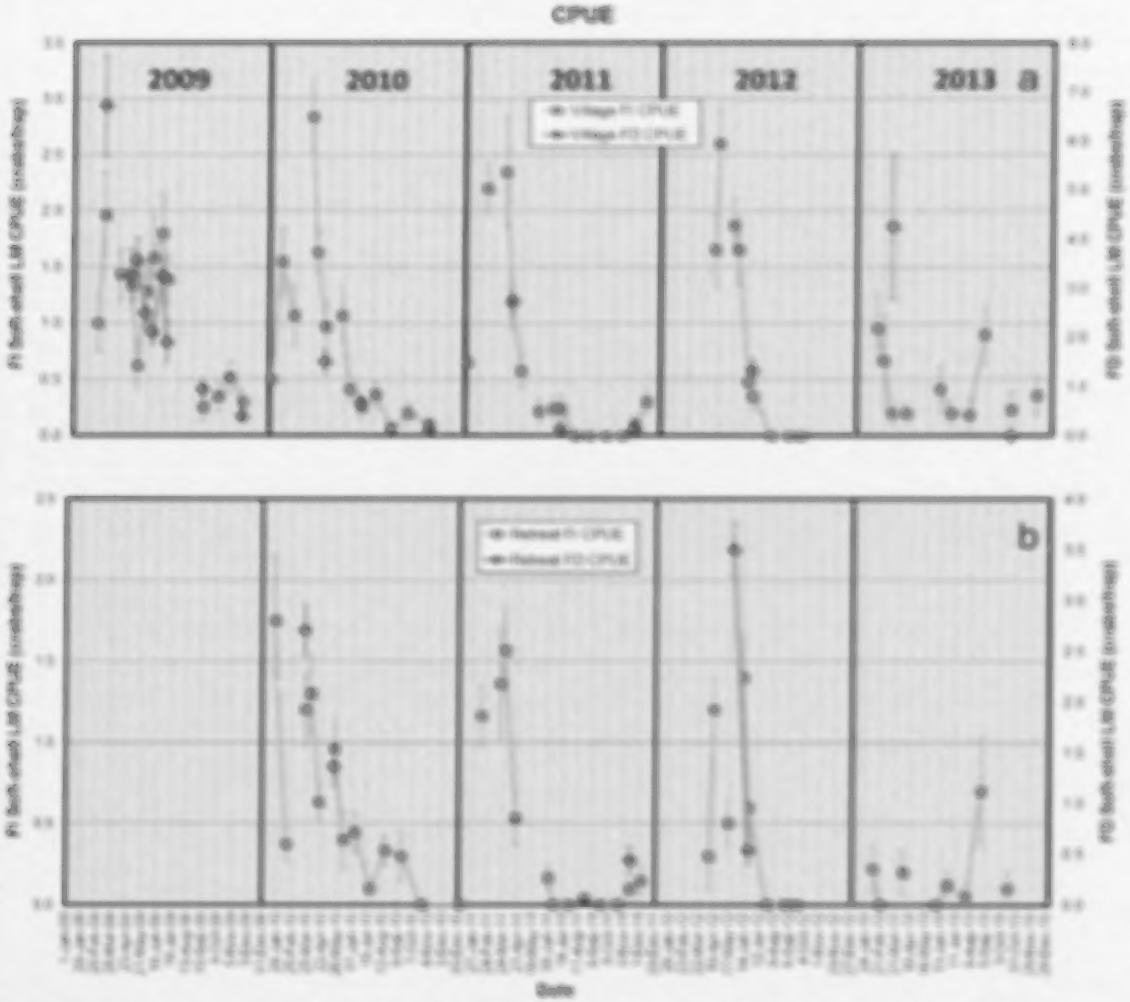


Figure B3. Crab Management Area (CMA) G 2009 to 2013 observed CPUE (± SE) from the fishery-independent (FI, blue) and fishery-dependent (FD, red) sampling programs in index areas (a) Village Channel and (b) Retreat Passage of soft-shell legal-sized male (LM) Dungeness Crabs. Note the sampling programs (FI and FD) did not start in Retreat Passage Index Area until 2010. Disconnected lines indicate scheduled sampling was missed between dates. Note varying scales on the y-axis.

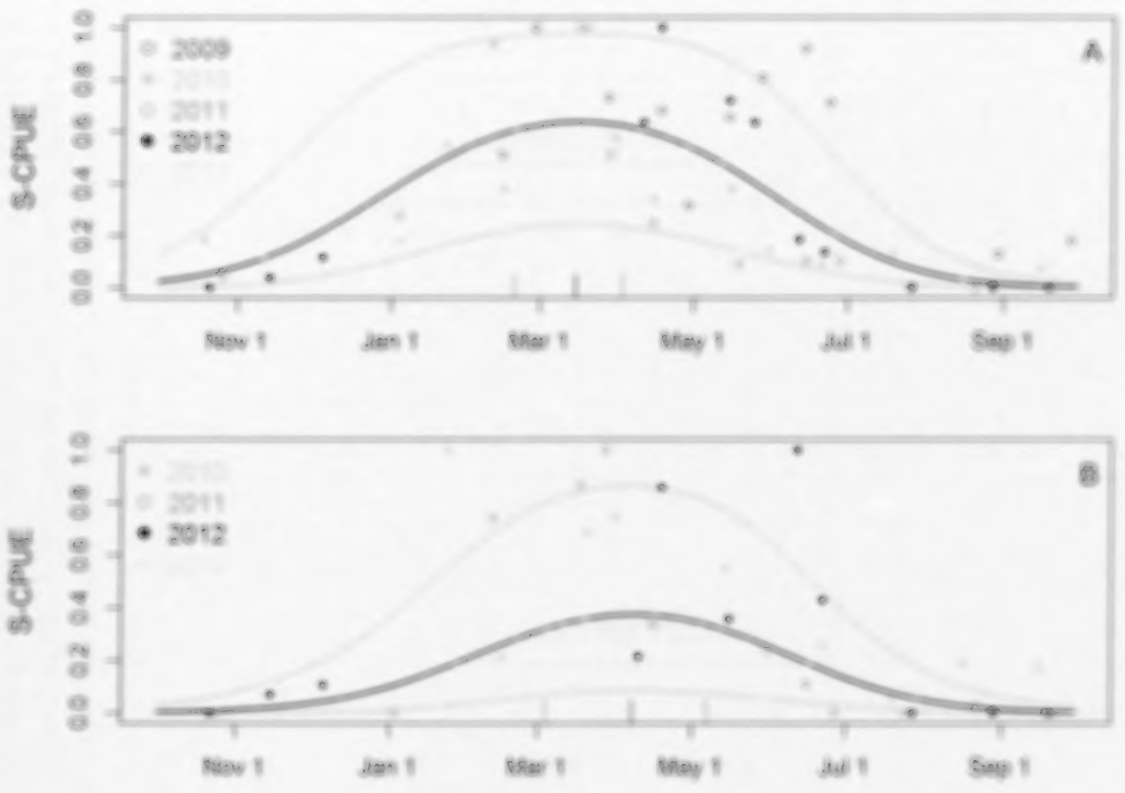


*Figure B4. Crab Management Area G 2009 to 2013 CPUE model results using fishery-independent (FI) data in index areas (a) Village Channel and (b) Retreat Passage for soft-shell legal-sized male Dungeness Crabs. The predictable variables 'days' and 'days^2' were significant. See Table B2 for details. (Red lines = 95% credible interval bounds (CI); green dashed lines = reductions from the peak proportion: from the top down, 0.95*Peak, 0.90*Peak, 0.85*Peak, 0.75*Peak and 0.50*Peak, respectively; red and black vertical lines above x-axis = peak date and 95% CI)*